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SRN4

an open-water passenger/car ferry

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SRN4

AN OPEN-WATER PASSENGER/CAR FERRY

For operation over open coastal waters, such as the English Channel, the optimum size of hovercraft is considered to be capable of operating in seas of up to 12 ft. wave height at speeds up to 70 knots over stage lengths of 100 miles.

The 165-ton SR.N4 is such a craft and is capable of carrying 50 tons of payload, equivalent to 34 cars and 174 seated passengers under these conditions.

The craft must also be capable of attaining a quick 'turn-round' and in this respect the central car deck has been provided with full-width doors fore and aft to provide a drive-on/drive-off facility. Amidships passenger doors, port and starboard, enable passengers to be embarked or disembarked concurrently with the vehicles.

Ease of servicing was constantly in mind during the design and the layout is such that all major components can be removed without any disruption of the structure. Simple ground equipment has been designed for the removal of the major items such as pylons, fans, gearboxes etc. and the engines are removed through hatchways in the roof using a standard mobile crane. Hydraulic jacks inserted through the floor enable the craft to be raised to a height sufficient to inspect the trunks and underside of the craft.

Reduction of noise was given special consideration when designing the craft particularly in respect of the propeller and fan speeds, and the siting of the engines.

british hovercraft corporation limited

YEOVIL SOMERSET, AND EAST COWES ISLE OF WIGHT, ENGLAND

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the basic craft

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the basic craft

GENERAL DESCRIPTION

Except for minor details the general arrangement shown is common for all versions of SR.N4 described in this brochure.

The 165-ton SR.N4 is an all-metal craft constructed mainly of light-alloy materials. The craft is powered by four Bristol Siddeley 'Marine Proteus' gas turbine engines located in pairs in two engine rooms at the rear of the craft. Each engine drives a propulsion air propeller and a centrifugal lifting fan. The propellers are mounted on pylons which can be pivoted to change the direction of thrust and so control the craft directionally. Fins mounted aft of the rear propellers move in conjunction with the rear pylons to give additional directional stability; the fin efficiency is increased by geared rudders.

The propeller transmission also drives the lifting fans which are mounted one below each propeller. Air is drawn by the fan through intakes on each side of the pylon and directed through plenum chambers under the passenger cabins into the peripheral trunks. From the trunks the air is directed inboard beneath the craft to create the air cushion.

The control cabin is sited on the cabin roof ahead of the forward pylons and provides accommodation for three crew plus one supernumerary.

The central main deck accommodates cars and the passenger cabins are along the sides of the craft and raised above the level of the car deck. At the forward end of the car deck is a hydraulically-operated ramp, which, when raised completely seals the car deck and when lowered enables the cars to drive off. At the aft end of the car deck are double doors which extend the full width of the deck. The passenger doors are in the sides of the craft and these in conjunction with retractable stairs enable the passengers to embark/disembark concurrently with the cars.

Air conditioning in the form of forced ventilation is provided in which the air is extracted by the main lifting fans and is replaced by fresh air through ventilators in the roof. Heating is by hot air bled from the main engines and fed through the ventilators.

Should the engines fail the craft has a reserve buoyancy of 250% and sufficient life jackets and inflatable life rafts are provided for all passengers. As the engines are sited aft and completely enclosed by fireproof bulkheads, fire risk has been minimised.

INTERNAL LAYOUT (BASIC CRAFT)

The internal layout in fig.1.1 shows how the design features of the basic craft have been influenced by the requirement to provide the maximum possible vehicle capacity while still having readily accessible and pleasantly situated passenger cabins.

Turn-round times, especially during peak operating periods, have a large influence on economics and in consequence great emphasis has been placed on the facility to achieve rapid turn-round times without imposing excessive penalties on the craft. To this end the wide hydraulically-operated bow ramp is an integral part of the craft and doors at the stern swing open to give access to the full width of the vehicle deck. Two rows of cars may be off-loaded simultaneously.

Retractable stairs on both sides of the craft enable passengers to embark or disembark concurrently with vehicle loading or unloading.

Car capacity of this layout, based on a random selection of a possible typical payload, is 34 cars. Block cars shown vary in size from four 10 ft. cars to two 17 ft. limousines.

Using 13 ft. 6 in. x 5 ft. as the average size of car, the capacity would still be 34 cars. Transverse width of the car deck is such that reasonable passageways may be left for passenger access.

From the car deck, steps give access to both forward and centre passenger cabins, the cabin floor level being 3 ft. above the car deck. With the engines well aft the application of modern soundproofing techniques and materials ensures a low sound level in these compartments. Passenger seats for 174 persons are shown together with baggage stowage space. Two toilets are fitted to this basic craft.

If it is assumed that the cars will each carry an average of four passengers and that they remain seated in their cars, then a 100% capacity payload for this layout will be approx. 61 tons at an A.U.W., with maximum fuel load, of approx. 176 tons.

At the other end of the scale assuming three passengers per car, not sat in their cars but occupying a passenger seat, then 100% capacity payload will be approx. 50 tons at an A.U.W. of 165 tons.

Passenger accommodation

In designing the basic craft, the layout was decided by the necessity for a quick turn-round without detriment to the comfort of the passengers. Comfortable 'bus' type seats are provided, forty-three in each bow cabin and forty-four in each side cabin, a total of 174. Overhead racks for light luggage are provided in the cabins and heavier baggage is stowed in vertical racks at the ends of the cabins and adjacent to the entrance doors. Three external doors are provided on each side of the craft, the main passenger entrance doors amidships and two smaller doors, one forward and one aft, which are normally used by the crew but in an emergency by the passengers. Sliding doors in all cabins give access to the vehicle deck.

The internal trimming incorporates soundproofing material and this, together with the siting of the cabins away from the main machinery, ensures that the minimum amount of noise penetrates to the cabins; the floor covering also assists in this respect.

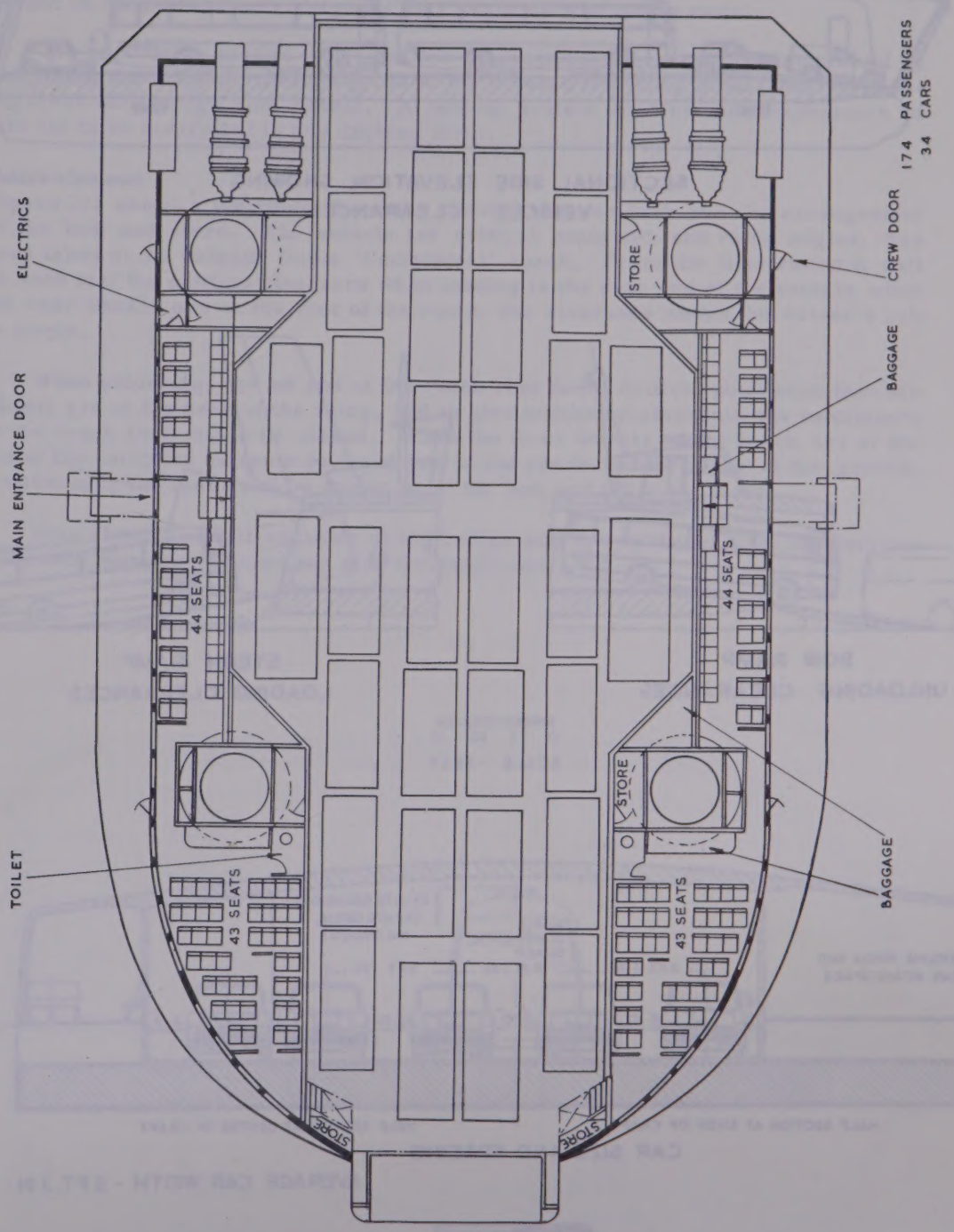
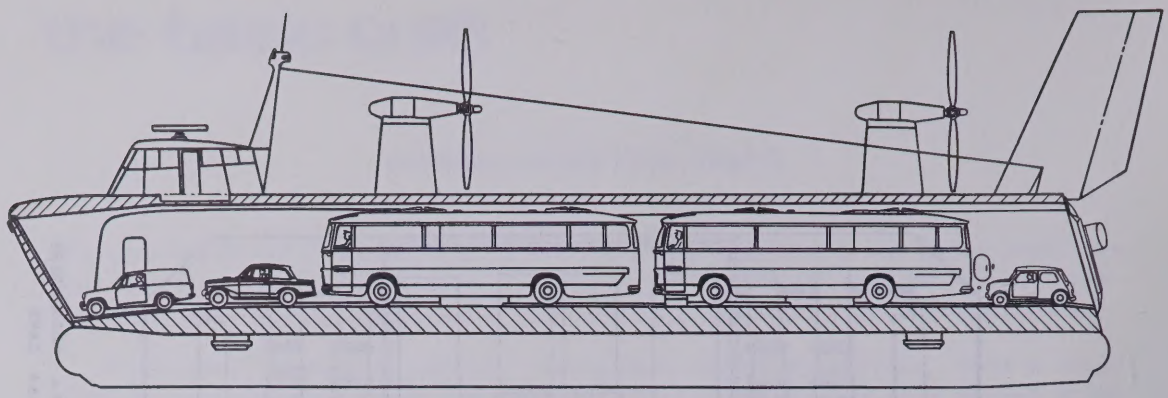
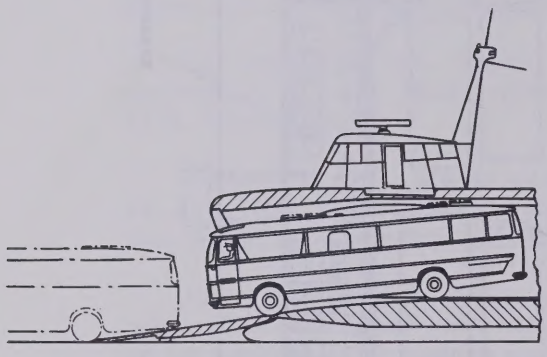


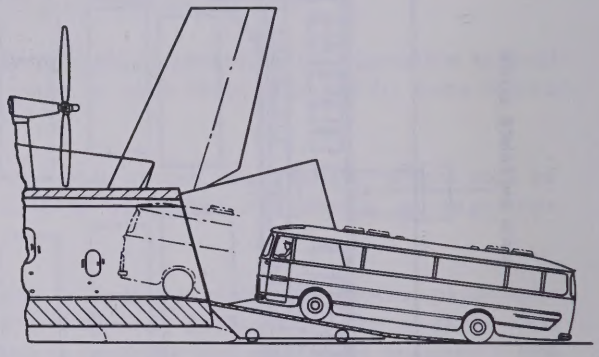
FIG. 1.1 LAYOUT OF BASIC CRAFT



SECTIONAL SIDE ELEVATION SHOWING
VEHICLE CLEARANCES

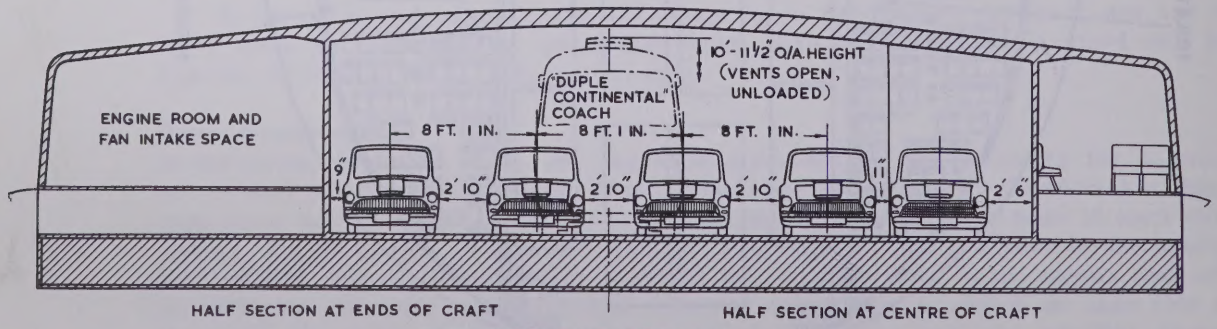


BOW RAMP
UNLOADING CLEARANCES



STERN RAMP
LOADING CLEARANCES

0 5 10 15
SCALE - FEET



CAR SIZE AND SPACING

AVERAGE CAR WIDTH - 5 FT. 3 IN.

0 1 2 3 4 5 10
SCALE - FEET

FIG. 1.2 LOADING CLEARANCES

A continuous row of large windows provides the passengers with an unobstructed view, particularly in the bow cabin. Selected windows are of the 'push-out' type so that in the event of an emergency they serve as emergency exits.

The ventilation system maintains the cabin conditions at a comfortable level by extracting the stale air through grills in the inboard trimming panels and introducing fresh air through roof panels. A heating system enables the temperature of this air to be controlled to any desired level.

Vehicle clearances

Figure 1.2 shows a longitudinal section through the car deck and the arrangement of the bow and stern. The vehicle for critical headroom and ramp angles, has been taken as an unladen Duple 'Continental' coach. From the illustration it will be seen that the critical clearance when loading is the rear end of the vehicle when the rear wheels are on the foot of the ramp; the clearance above the driver's cab is ample.

When unloading, the aft end of the coach roof is the critical point when the rear wheels are at the head of the ramp, and to give maximum clearance the ventilators in the coach roof should be closed. When the front wheels of the coach are at the toe of the ramp the extreme forward end of the coach is well clear of the ground. If necessary the coach can be driven on at the bow and off at the stern.

Also shown are half-sections at the centre and end of the craft to indicate the clearance between vehicles and also the headroom.

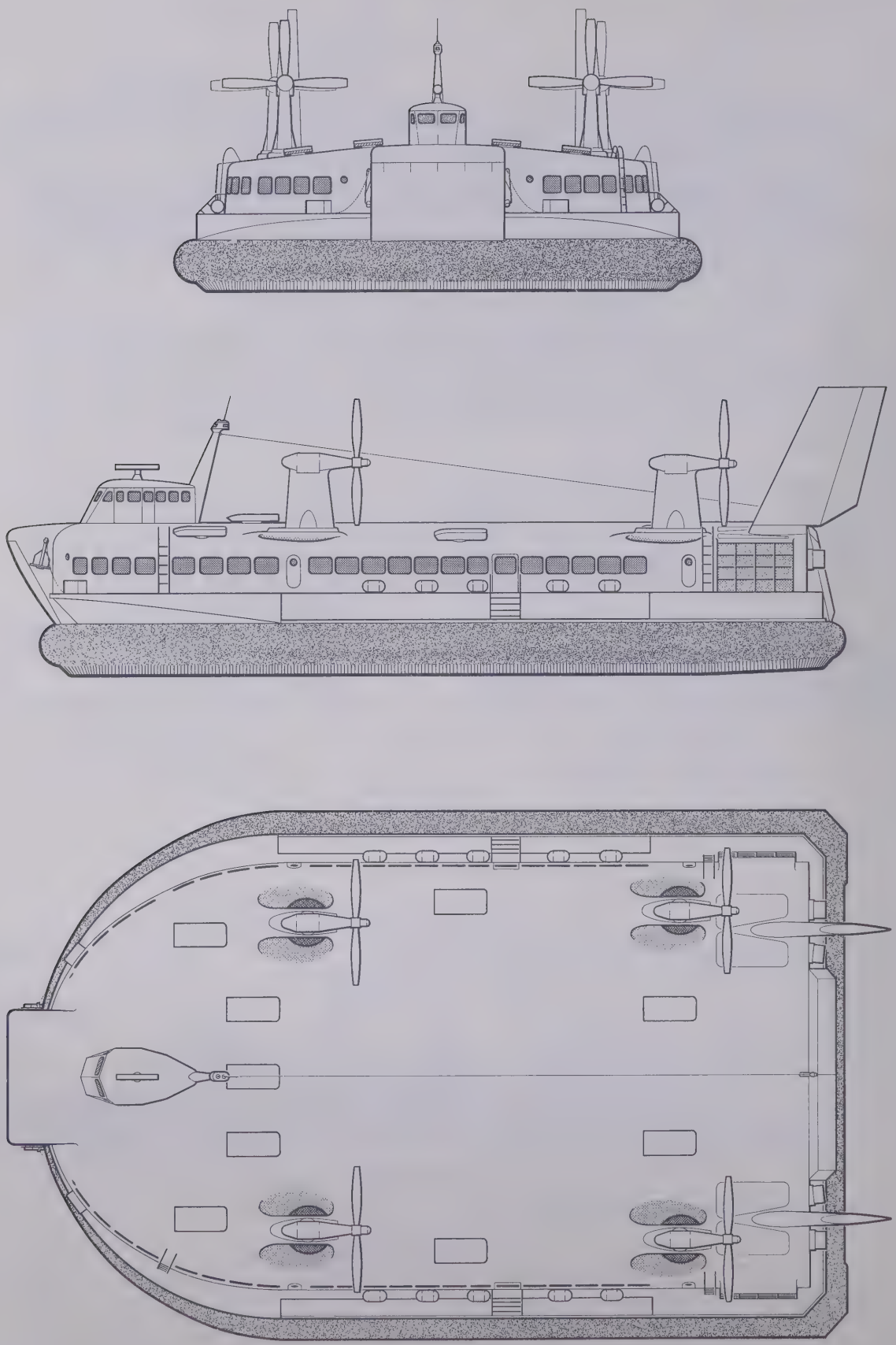


FIG.1.3 THREE-VIEW GENERAL ARRANGEMENT

LEADING PARTICULARS

CRAFT

Type	SR.N4 passenger/car ferry
Duty	Amphibious transport vehicle
Operating crew ..	Commander, engineer, navigator/radio operator
Capacity	174 passengers and 34 cars

Supplementary crew in the form of stewards and deckhands would be required, dependent upon the role. A nominal total crew of five has been allowed in the weight summaries.

Dimensions

Length, overall	130 ft. 2 in. (39,68 m.)
Beam, overall	76 ft. 10 in. (23,46 m.)
Height, overall	42 ft. 5 in. (12,95 m.)
Bow ramp aperture	18 ft. x 11 ft. 6 in. (5,5 m. x 3,5 m.)
Stern door aperture	31 ft. x 11 ft. 6 in. (9,45 m. x 3,5 m.)
Vehicle deck headroom	11 ft. 3 in. (3,4 m.)
Cushion area	7,342 sq.ft. (682 sq.m.)
Cushion loading at 165 tons A.U.W. ..	50 lb./sq.ft. (244 kg./sq.m.)
Buoyancy reserve at 165 tons A.U.W.	250% (Total buoyancy approx. 550 tons)

POWER PLANTS AND TRANSMISSION

ENGINES - MAIN	Four Bristol 'Marine Proteus' gas turbines
	Maximum continuous power 3,400 s.h.p.
	Maximum permissible power 4,250 s.h.p.
- AUXILIARY	Two, Rover 1S/90 gas turbines
TRANSMISSION	B.H.C. integrated drive for lift fan and propulsion propeller
PROPELLERS	Four, Hawker Siddeley Dynamics, four-bladed, 19 ft. (5,8 m.) dia. controllable pitch
LIFT FAN	Four, B.H.C., twelve-bladed, 11 ft. 6 in. (3,5 m.) dia. centrifugal, fixed pitch
FLEXIBLE TRUNKS	7 ft. (2,13 m.) combination type

SYSTEMS

FUEL

Type	Standard aviation kerosine D.E.R.D.2494 (AVTUR) (diesel fuel, specification DEF 2402-A may be used as an alternative)
Tankage	Twelve, in four groups of three
Capacity	
Normal	3,400 Imp. gall. (15 456 litre)
Maximum	4,500 Imp. gall. (20 457 litres)

LEADING PARTICULARS

SYSTEMS (Cont'd)

Pumps	
Feed and transfer	S.P.E.6516, centrifugal
	Feed - 400 g.p.h. (1 818 litres per hr.) at 20 p.s.i. (1,4 kg. sq.cm.)
	Transfer - 3,900 g.p.h. (17 730 litres per hr. at 10 p.s.i. (0,7 kg. sq.cm.)
OIL	
Pumps, hydraulic	
Pylon and fin operating pumps	Lucas 1P 500 - 3,000 p.s.i. (210 kg. sq.cm.)
Propeller pitch pump	Integral Y836 Mk.1 680-920 p.s.i. (48-65 kg. sq.cm.)
Ramp, rear door, stairway and fan intake shutter pumps ..	Integral Y793 Mk.1 - 3,000 p.s.i. (210 kg. sq.cm.)
Pumps, lubricating	
Gearbox pumps	Plessey Gamma 72 - 30 to 50 p.s.i. (2,1 to 3,5 kg. sq.cm.)
Bevel gearbox scavenge pump	Plessey Gamma A 140X
Oil - hydraulic	Shell Tellus 27
Oil - lubrication and propeller pitch change ..	OX-38 (D.E.R.D.2487)
ELECTRICAL	
Generation	Two, turbo-alternators, driven by A.P.Us, supply 208 volts, 400 c/s, 3-phase
Batteries	Two, 28-volt
External supplies	200 volt A.C. 28 volt D.C.

WEIGHTS

Nominal weights	
Basic weights - equipped with full furnishings, radar, radio and safety equipment	101·5 tons (103,1 tonnes)
Disposable load	63·5 tons (64,5 tonnes)
Capacity fuel load	16 tons (16,26 tonnes)
Normal A.U.W.	165 tons (167,6 tonnes)
Overload disposable load	83·5 tons (84,8 tonnes)
Overload A.U.W.	185 tons (187,9 tonnes)

LEADING PARTICULARS

WEIGHTS (Cont'd)

Basic craft - 34 cars and 174 passengers

Basic weight			101·5 tons (103,1 tonnes)
Disposable load			
Crew	0·45		
Cars, passengers and luggage	50·55		
Fuel	12·0		
Total	63·0	.. ..	63 tons
Normal A.U.W.			164·5 tons (167,1 tonnes)

PERFORMANCE SUMMARY

The following estimated performance figures have been derived from established prediction methods with due account taken of towing tank and wind tunnel tests using scale dynamic models.

With the exception of the overwave and gradient performance, the performance is given for calm water still air conditions.

All values are quoted under I.S.A. conditions.

No allowance has been made for the effects of 'plenum bleed' air intakes to the Proteus engines which have distinct advantages when operating in cold climates (de-icing) and minimises the ingress of dust or sand when operating in arid and desert areas.

It should be noted that the quoted maximum speeds assume the craft to be correctly trimmed, whereas the 'Service Average' speed is a typical speed readily achieved by the average commander.

The 'Service Average' speed has been found to be some 87 - 90% of the maximum from experience obtained with the production SR.N6.

The quoted mean operating weight is a typical average of the passenger/car layouts in either the basic or standard form, assuming 75% load and half fuel used.

Mean operating weight	147·5 tons (150 tonnes)
Max. speed (optimum trim) - max. power ..	77 knots (143 km./hr.)
Max. speed (optimum trim) - max. cont. power ..	70 knots (130 km./hr.)
Service average speed - max. cont. power ..	61 knots (113 km./hr.)
Airspeed into wind in 4 - 5 ft. waves .. (Channel type seas)	56 - 65 knots (102 - 120 km./hr.)
Airspeed into wind in 8 - 10 ft. waves .. (Channel type seas)	50 - 60 knots (93 - 111 km./hr.)
Time to accelerate to 50 knots	55 sec.

LEADING PARTICULARS

PERFORMANCE SUMMARY (Cont'd)

Normal stopping distance from 50 knots	525 yards (480 m.)
Emergency ditching distance from 50 knots ..	175 yards (160 m.)
Normal turn radius at 40 knots	860 yards (786 m.)
Endurance on 12 tons fuel at max. cont. power	3 hours
Calm water range at max. cont. power	175 n.miles
Negotiable gradient from standing start	1 : 11

INSTRUMENTS

General

Trim, pitch and roll
Rate of turn
Propeller pitch angle
Pylon angle
Fin angle
Clock
Air speed
Water speed

Engine

Compressor r.p.m. (4)
Turbine r.p.m. (4)
Jet pipe temperature (4)
Oil pressure (4)
Oil temperature (4)
Oil contents (4)
Fire warning - Zones 1 and 2
Engine torque

Auxiliary power units

Jet pipe temperature
Oil pressure
Fire warning

Transmission

Lubricating oil pressure (4)
Lubricating oil temperature (4)
Lubricating oil tank contents (4)
Hydraulic oil pressure - pylon (4)
Hydraulic oil pressure - fin (2)

Propeller

Lubricating oil pressure (4)
Lubricating oil tank temperature (4)
Lubricating oil tank contents (4)
Pitch control oil pressure (4)

Fuel

Contents (4)
Inlet pressure

Electrical

Generator amps. (2)
Generator volts (2)
D.C. volts (2)
Generator failure (2)
Generator frequency (2)
External supply amps. (1)
Main battery supply amps. (1)
Reserve battery amps. (1)
T.R.U. amps.
Magnetic indicator

Navigation

Gyro compass
Remote reading magnetic compass

COMMUNICATIONS

Radio V.H.F. (F.M. Marine)

Intercommunication

Control cabin headsets
Engine room and rear bulkhead headsets
External headset points
Passenger cabin telephone headsets
Car deck headsets
Car deck loudspeakers
Passenger cabin loudspeakers
Microphone-control cabin
Control cabin intercomm./public address station box

FIRE PROTECTION

Firewire detection
Automatic B.C.F. extinguishers (14)
Smoke detection
Hand extinguishers (18)

STANDARD SPECIFICATION EQUIPMENT (Cont'd)

SAFETY EQUIPMENT

Lifejackets (184)

Lifebelts (2)

Life rafts - 27 seats (8)

Flares

Floating lines

Axes (8)

Torches (6)

First-aid kit (2)

Emergency tool kit

Boat hooks (2)

Signalling lamp

Anchors (2)

Towing straps

MISCELLANEOUS

Windscreen wipers (4)

Windscreen washers (4)

performance

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Deceleration	2.9
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Turning	2.11
Payload–range	2.12

performance

This section gives preliminary performance estimates for the range of operating A.U.Ws of the basic and standard craft. In deriving these estimates a large amount of SR.N4 model tests together with full scale data on existing Westland craft have been analysed and the results incorporated. Of the full scale data, particular use has been made of the SR.N5 results since this craft has a shape which is very similar to SR.N4.

The estimates refer to skirts 7 ft. in length, these are of the combined bag and fingered type, where the lower part of the skirt is in the form of fingers through which the cushion air is directed. Skirts of this type are already in use on SR.N6, giving an improved ride in waves over that found from the earlier skirts from which they are derived.

With the exception of engine operating conditions, overwave and gradient capability, the performance is given for calm water and still air conditions, all values are quoted for I.S.A. conditions unless otherwise stated.

No allowance has been amde for the effects of taking the Proteus engine air from the plenum chamber which has a distinct advantage when operating in cold climates, for de-icing, and also minimised the ingress of sand and dust when operating sand and desert areas. However, experience on SR.N6 indicates that the loss of performance caused by taking the engine air from the plenum chamber is not more than 10% and it is expected that the corresponding loss of performance on SR.N4 will be less than this..

Since in the integrated lift and propulsion system, the power required for propulsion varies with forward speed, the amount of power available to the lift fans will vary with speed for a constant total power output from the engines.

performance

THRUST AND DRAG

The total thrust and total drag acting on the craft in still air and calm water are plotted in fig.2.1 against forward speed for the mean A.U.W. of 147·5 tons.

The drag curve is composed of aerodynamic profile drag, the momentum drag of the air entering the fan intake and the hydrodynamic drag, which includes wave drag and water wetting drag. The wave and water wetting drags cause the peak in the drag curve at 21 knots. With further increase in speed the contribution of the wave drag diminishes while the other components increases. The thrust is composed of three terms - propeller thrust, engine exhaust and cushion jet thrust - the reduction in total thrust will increase in forward speed being due to the typical fall in propeller thrust. Where the thrust and drag curves intersect the craft is in equilibrium and up to this intersection the difference between the curves is a measure of the acceleration which can be achieved at a given forward speed. Two thrust curves are shown, the lower showing the thrust produced when the engine is operating at the maximum continuous rating of 3,400 s.h.p., this gives a maximum speed at this A.U.W. of 70 knots. The maximum speed can be increased to 77 knots by using the limited duration maximum rating of the engines. However, use of the maximum rating is not recommended for general use because of its marked effect on engine life and consequent adverse effect on operating costs.

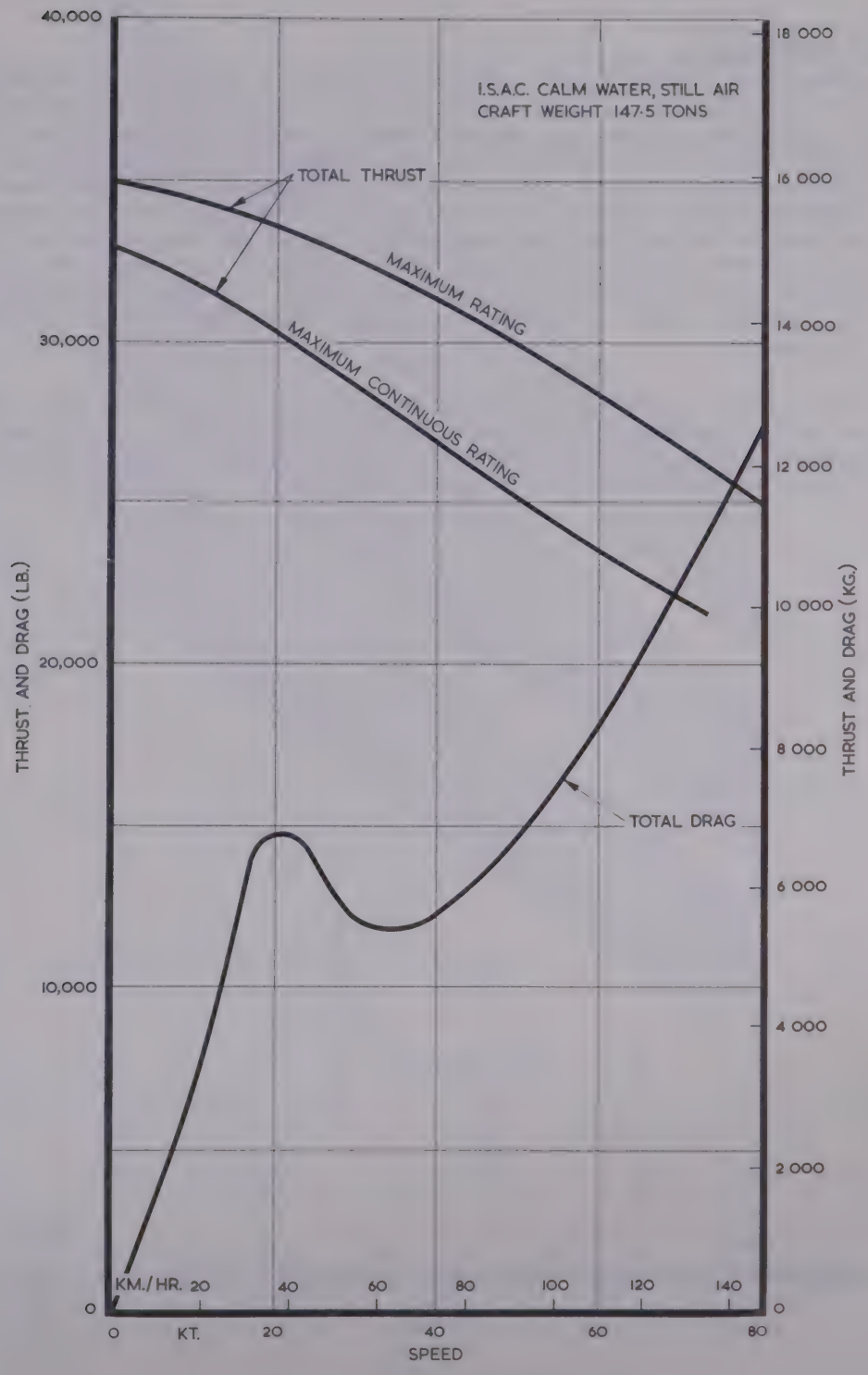


FIG. 2.1 THRUST AND DRAG

performance

SPEED PERFORMANCE

The estimated forward speed performance is shown in fig.2.2 for a range of A.U.Ws in calm water and still air at the maximum continuous engine ratings under I.S.A. conditions together with the maximum continuous rating at I.S.A. +15°C. Experience with SR.N5 and SR.N6 craft has shown that apparently identical craft can, under similar conditions, have different performances. This difference can be accentuated by the degree of skirt tailoring applied to a particular craft, the engine condition and the operating trim as well as by the handling of the craft which will vary between commanders. These factors lead to the craft performance being indicated as a band rather than as a single line. Again it must be stressed that use of the maximum engine rating is not recommended other than in exceptional circumstances.

Initially the craft will be cleared to a maximum A.U.W. of about 165 - 170 tons for use in the passenger and passenger-car ferry roles. However, it is intended that the craft will eventually be cleared for operation in the freight role at A.U.Ws, as indicated on the figure, up to about 200 tons in suitable ambient conditions.

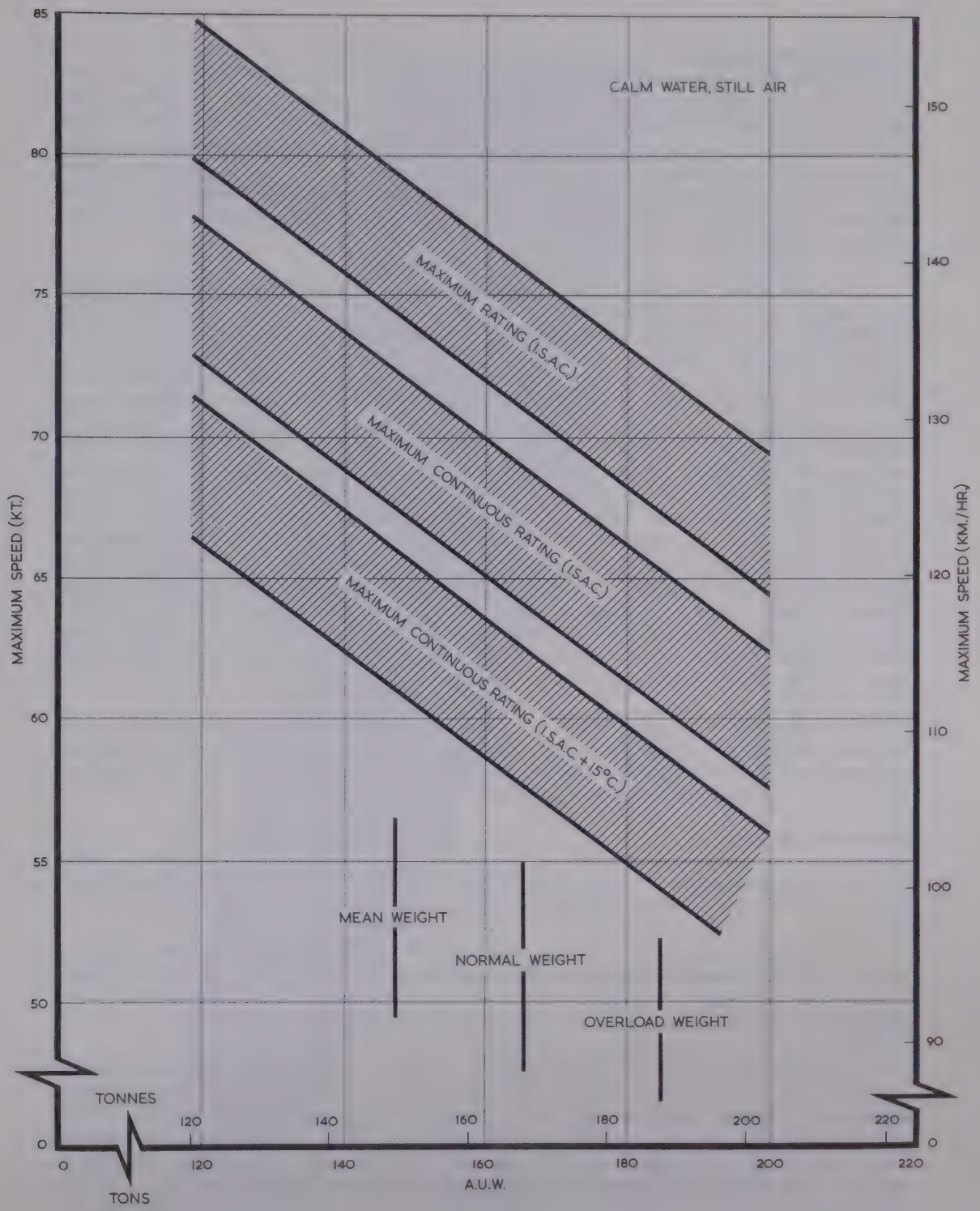


FIG. 2.2 SPEED PERFORMANCE

OVERWAVE PERFORMANCE

Although the SR.N4 hovercraft will not be operational until late in 1967, considerable experience of craft sea-keeping capabilities has been gained from operations with SR.N2, 3, 5 and 6. Much of this experience has been gained from the SR.N6 hovercraft which have accumulated a total of over 9,000 hours of operation in areas around the British Isles, Norway, the Baltic and the Far East. During these activities the craft have frequently negotiated waves of up to ten feet in height and encountered wind speeds of up to 35 knots, while maximum wind speeds of the order of 40 knots have been recorded.

The data gathered from these trials and commercial operations, together with the results of model testing in both towing tank and radio-controlled free flight conditions, has been used to estimate the performance of SR.N4. However, it will be appreciated that since the craft performance in any particular sea state is a complex function, not only of wave height and wind speed and their direction relative to the craft, but also of wave height, craft condition and commander ability, it is extremely difficult to predict the overwave performance accurately. Further, it has been noted that in operations across any particular stretch of water the craft has encountered three of four different sea states. This feature of varying sea state is well illustrated by conditions observed from SR.N6 hovercraft on the Ramsgate to Calais route. With a 25-knot south-westerly wind there may be three to four foot waves approaching from two different directions outside Ramsgate Harbour, and, with relatively shallow water on the Goodwin Sands a short 'pinnacle' five to six foot sea, depending on the direction of the tide, of about craft length. In mid-Channel the wave height is likely to be eight to ten feet with a length of about two to three times the craft length, and outside Calais, due to the shallowing water, a short breaking 3 to 3·5 foot sea is encountered, very similar to that which occurs off Southsea beach with a south-easterly wind.

To overcome this difficulty the SR.N4 sea-keeping capability has been presented in graphical form in which the bands represent the spread of probable performance and this includes the effects of the parameters discussed above. This is shown on fig.2.1 to 2.6 for a craft weight range of 147·5 - 165 tons.

Wave height – Wind speed

Figure 2.3 shows the boundaries of maximum wave height as a function of wind speed for the Ramsgate - Calais area of the Channel, based on observations made from SR.N6 during a series of proving trials.

No unique curve can be drawn to represent this relationship since the maximum wave height is a function not only of the wind speed but also of its direction, which determined the fetch or distance of water over which the wind is blowing, the direction of the tide relative to the wind and the depth of water.

The figure illustrates the wide variation of maximum wave height that has been observed for a given wind speed in the Ramsgate - Calais area of the Channel. Typically a 15-knot wind can give wave heights of from 2 feet up to nearly 10 feet and an 8 foot sea can be produced by wind speeds of from 13 knots up to 30 knots. This shows how estimates that are based upon limited data can lead to significant errors in the estimation of sea-keeping ability on any particular route. This is particularly true of the Channel short sea routes, where the venturi effect of the land masses can produce a marked increase in the speed of the tide and perhaps a 20% increase in wind speed when compared with measurements taken outside the area.

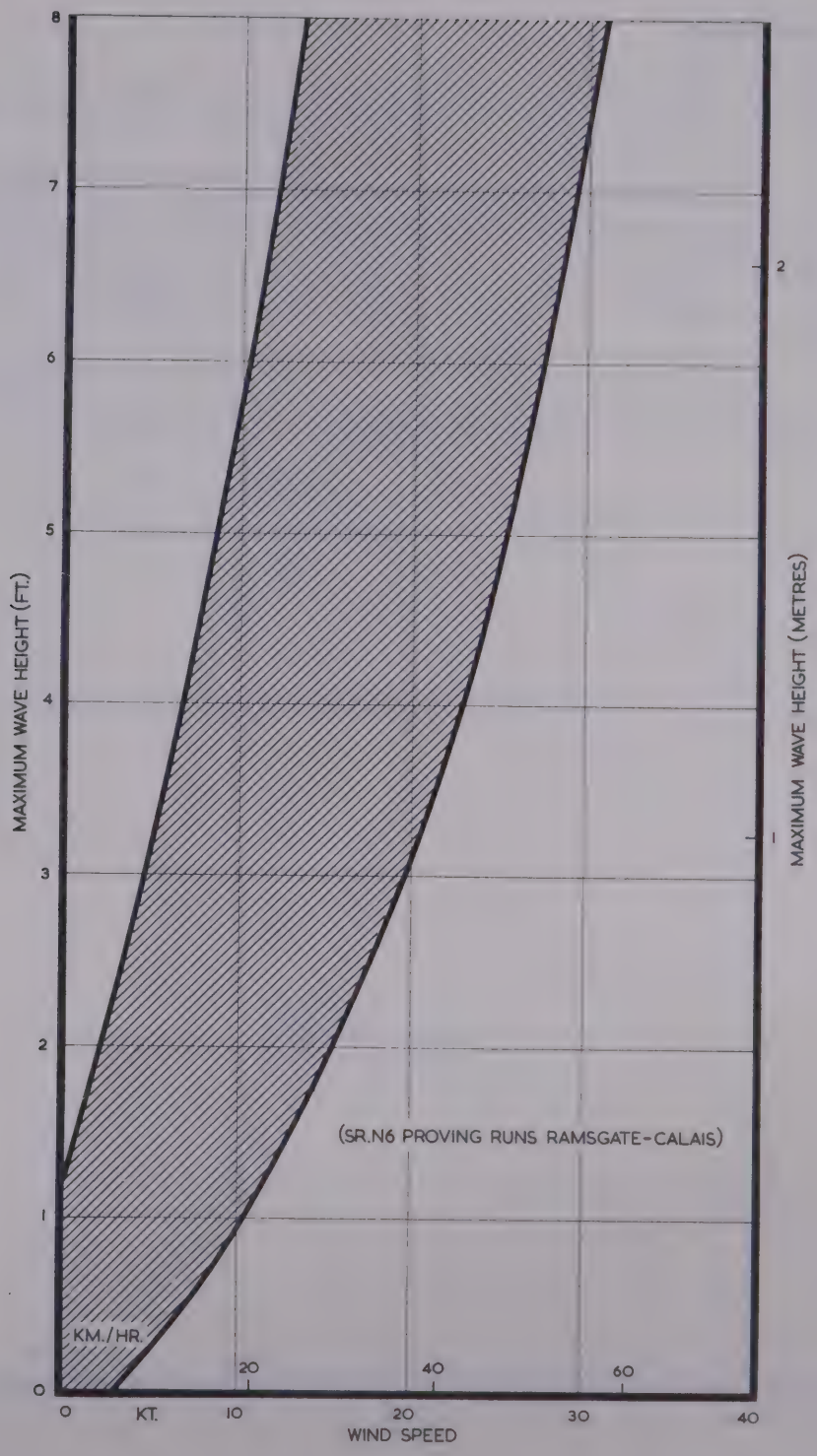


FIG. 2.3 OBSERVED WAVE HEIGHT–WINDSPEED (ENGLISH CHANNEL)

OVERWAVE PERFORMANCE

Craft air speed – Wind speed

The calculated air speed at the maximum continuous power engine rating is given as a function of wind speed in fig.2.4. Implied in this figure are the wave height - wind speed relationships of fig.2.3.

Two performance bands are shown, into wind and down wind, which occur because of the interchange between aerodynamic and hydrodynamic drags as the wind direction changes. Clearly it will be generally possible to attain higher air speeds into wind than down wind. The across-wind curves have been omitted for clarity of presentation but can be assumed to lie between the into wind and down wind curves.

With a 15-knot wind the probable air speed can range from a maximum of nearly 70 knots into wind to a minimum of about 40 knots down wind.

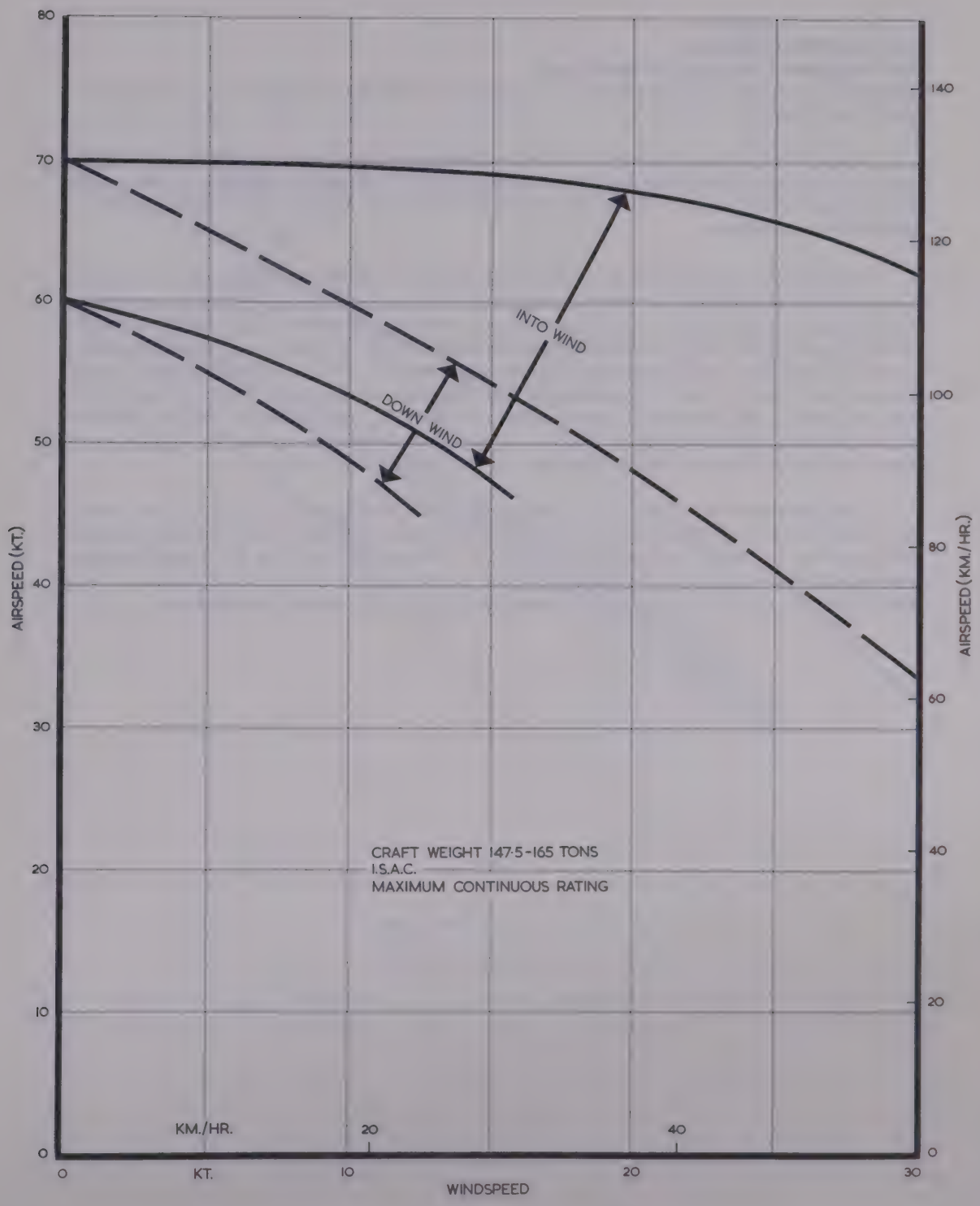


FIG. 2.4 AIRSPEED–WINDSPEED

OVERWAVE PERFORMANCE

Craft water speed – Wind speed and service speed

Figure 2.5 shows the envelopes of estimated craft water speed as a function of wind speed and direction.

Since for a given water speed the craft drag is higher into wind than down wind, and, in addition, the propeller thrust tends to decrease with increase in air speed, the highest water speeds for a given wind speed are likely to be obtained in the down-wind direction.

In particular for SR.N4 the calculated water speed down wind is anticipated to be substantially constant in the Channel for wind speeds up to 15 knots. Into wind there will, however, be a more pronounced reduction in water speed with increase in wind speed, due to the increased aerodynamic drag, giving water speeds ranging from 33 up to 55 knots, depending on the wave height, into a 15-knot wind. Again across wind speeds can be assumed to fall between the limiting cases of down wind and into wind. If required a substantial increase in performance can be obtained by use of the maximum engine rating. Typically use of this rating increases craft speed by about 7 knots albeit considerably reducing engine life.

Also shown on this figure is a service speed band which indicates the likely SR.N4 service or ground speed as a function of wind speed. This can be used for determining a rough indication of service schedules since it is approximately equivalent to the mean of the bottom of the down wind and into wind bands at high wind speeds, and this includes the most adverse wind - wave combinations.

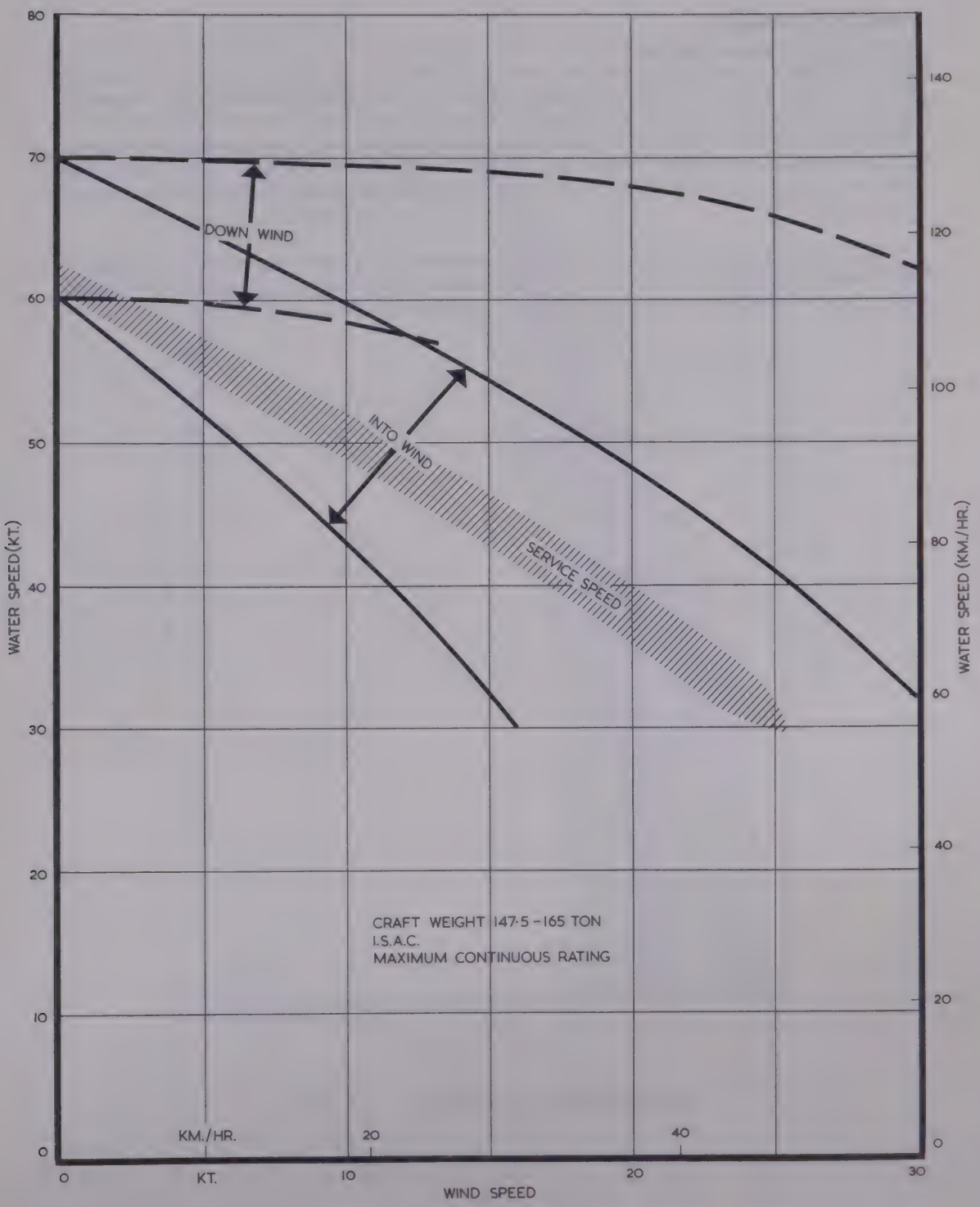


FIG. 2.5 WATER SPEED–WIND SPEED

OVERWAVE PERFORMANCE

Craft air speed – Maximum wave height

The envelope of craft air speed into wind as a function of maximum wave height is given in fig.2.6 for the Channel wave height - wind speed relationship shown in fig.2.3. It can be seen that wave height, up to say 6 ft., is likely to have very little effect on craftaair speed into wind, the reduction in air speed being about 10%. This is because the higher waves are being negotiated at a lower water speed and thus the hydrodynamic drag as well as the aerodynamic drag remains substantially constant.

Also shown in fig.2.6 is the assumed service or ground speed band of fig.2.5 converted to air speed into wind and the effect of operating at the maximum engine rating and the maximum continuous engine rating at I.S.A. +15°C.

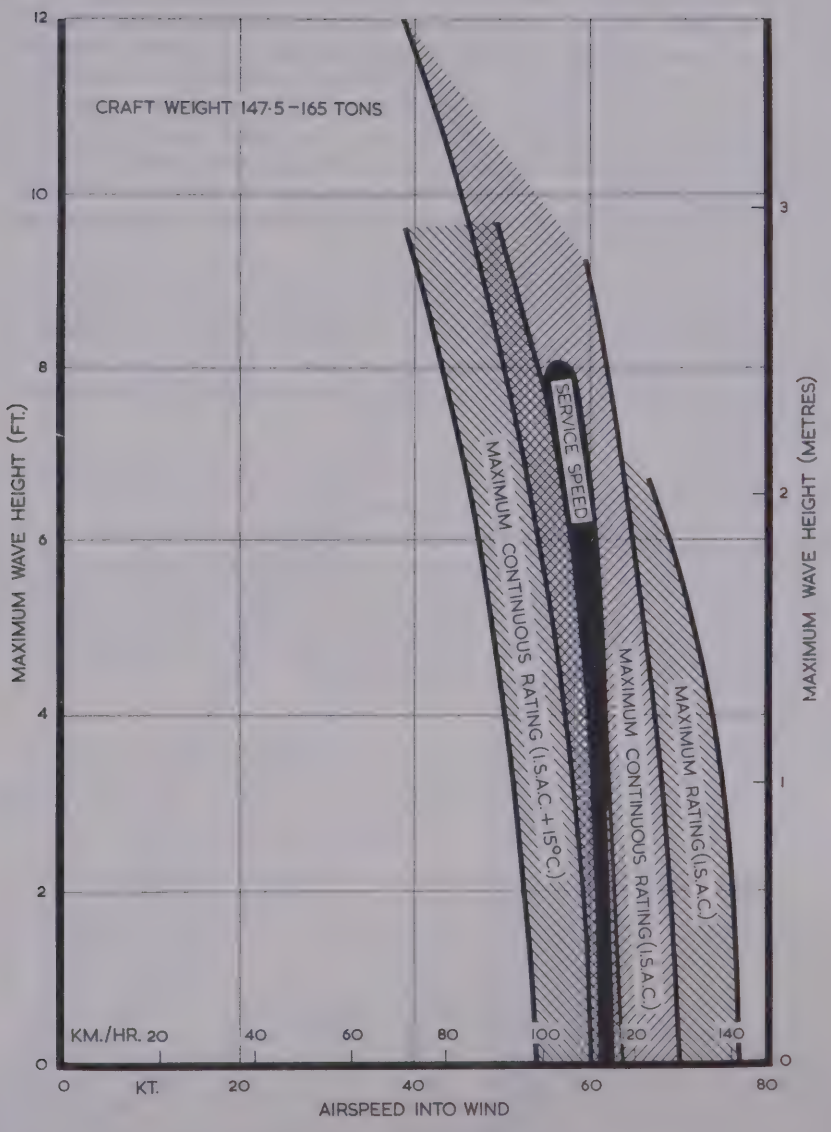

CRAFT WEIGHT 147·5 – 165 TONS
SERVICE SPEED
MAXIMUM CONTINUOUS RATING (I.S.A.C. + 15°C.)
MAXIMUM CONTINUOUS RATING (I.S.A.C.)
MAXIMUM RATING (I.S.A.C.)
MAXIMUM WAVE HEIGHT (FT.)
MAXIMUM WAVE HEIGHT (METRES)
KM./HR. 20 40 60 80 100 120 140
0 KT. 20 40 60 80
AIRSPEED INTO WIND
0 2 4 6 8 10 12
0 1 2 3

FIG. 2.6 OVERWAVE PERFORMANCE

ENGINE OPERATING CONDITIONS

Figure 2.7 shows the variation of engine output power in I.S.A. conditions with turbine speed for a range of compressor r.p.m. with craft operating conditions superimposed. In most conditions the engine would be operating within the area shown, and to achieve the performance shown in this brochure the compressor would need to be run at 11,250 r.p.m., the cruise or maximum continuous rating of this engine. Operation at higher compressor speed up to the maximum value of 11,750 r.p.m., corresponding to 4,200 s.h.p. from each engine at the maximum turbine speed of 10,720 r.p.m. is possible, but will greatly reduce the engine life. Conversely the engine life is increased if the operators schedules are such that they can be achieved, if only occasionally, on power ratings below maximum continuous.

In temperatures above I.S.A. the engine output at a particular compressor speed or throttle setting, falls with increase in temperature, typically by about 0·8% for each degree centigrade rise at the maximum continuous rating, and rises with decrease in temperature. However, to achieve a high engine life it is recommended that for operation in cold climates the engine output is restricted to a maximum of 3,400 s.h.p.

When the craft is in operation the turbine speed will vary from 6,800 r.p.m., where the fan will generate a pressure sufficient to just 'life off' the craft from the landing pads up to the maximum turbine speed which is governed to 10,720 r.p.m. Within the operating range of the turbine 6,800 - 10,720 r.p.m., the minimum power required from the engine is given by the lower boundary of the operating region. The minimum engine power includes a transmission loss of $2\frac{1}{2}$% together with an allowance of 25-35 s.h.p. for auxiliaries, the power required by the fan, and the power required for the propeller at zero pitch.

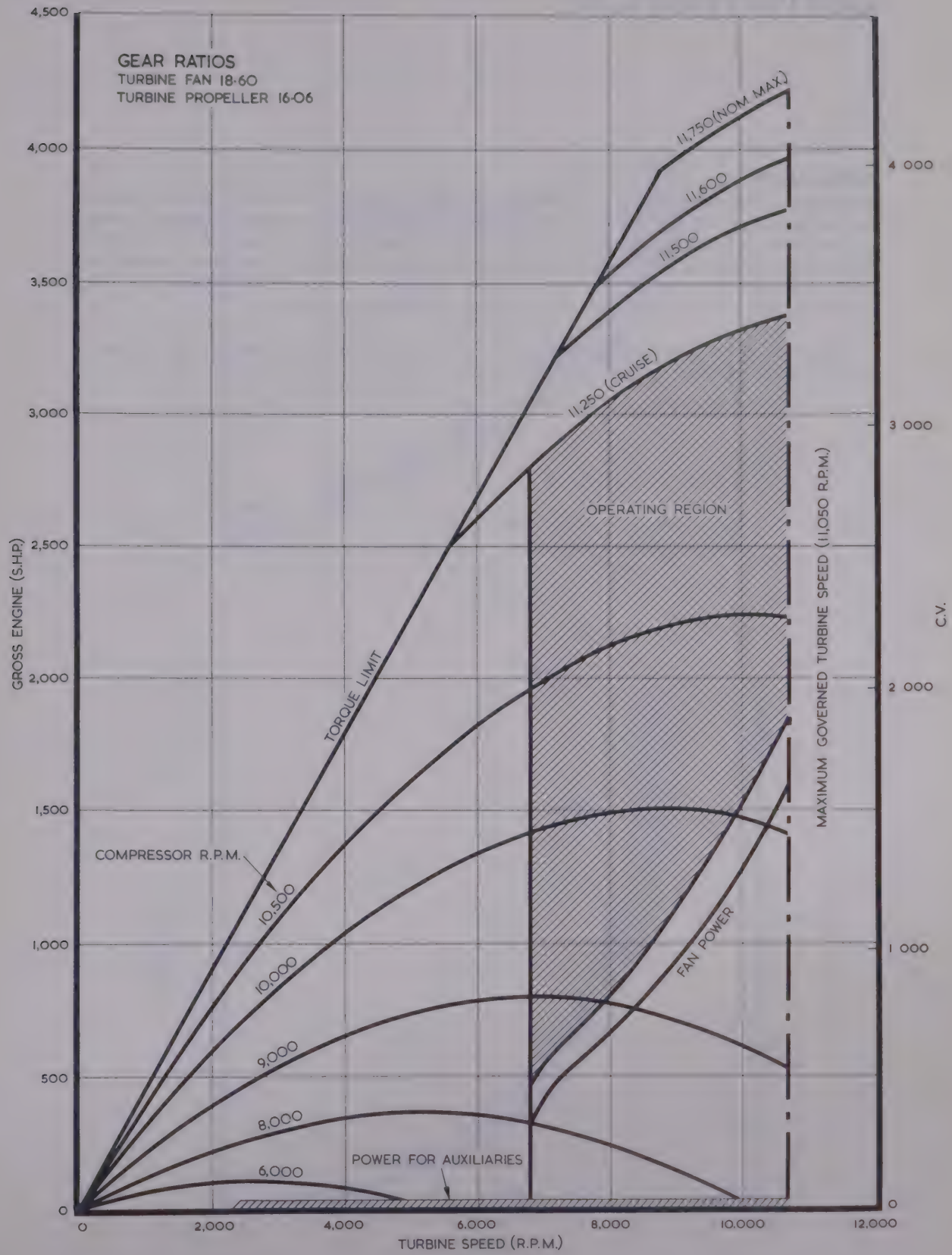
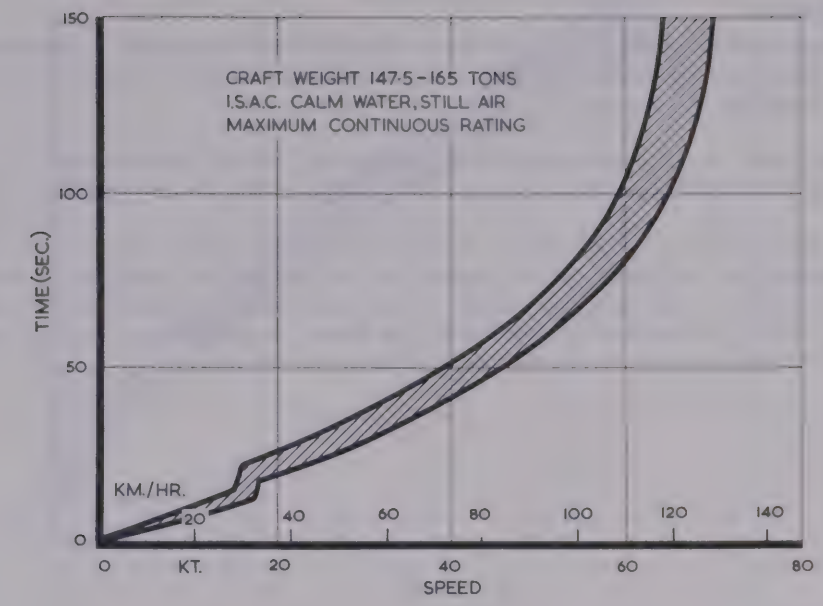


FIG. 2.7 ENGINE OPERATING CONDITIONS

ACCELERATION

The time curve given in fig.2.8 shows the time required to reach a given speed at the mean weight of 147·5 tons when using the maximum continuous power rating. To reach a cruising speed of 50 knots takes approximately 55 seconds. The discontinuity occurring at 21 knots is caused by the peak hydrodynamic drag which reduces the net thrust on the craft as shown in fig.2.1. After this speed has been achieved, the wave drag diminishes rapidly as speed increases.

The distance curve given in fig.2.5 shows the distance required to achieve a given speed. At this weight, 50 knots is reached in some 880 yards.



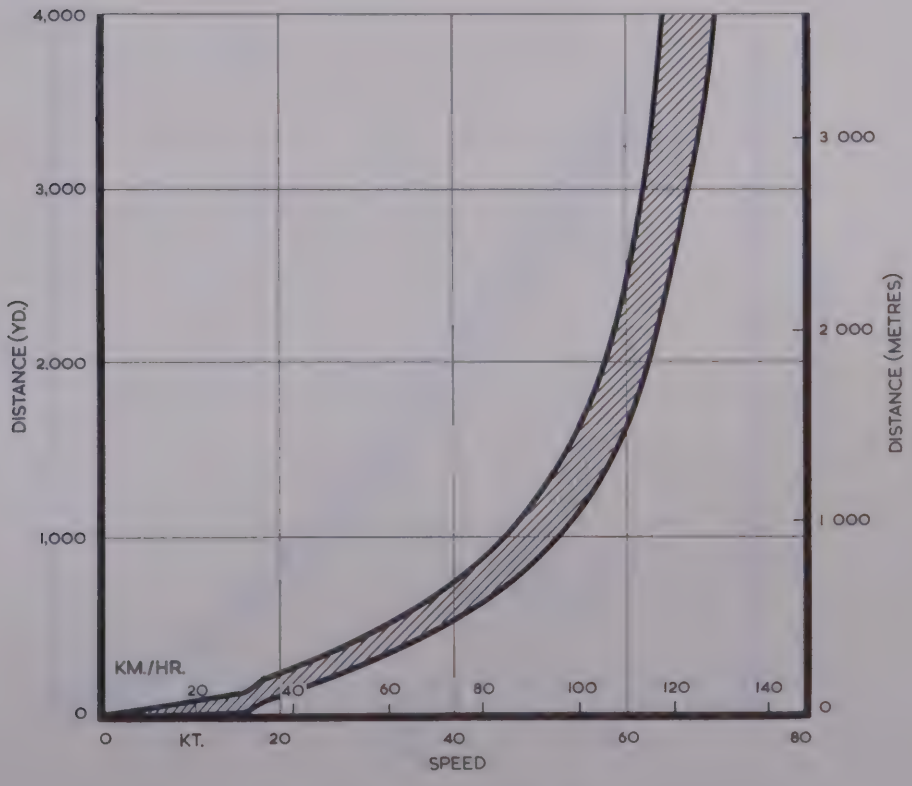


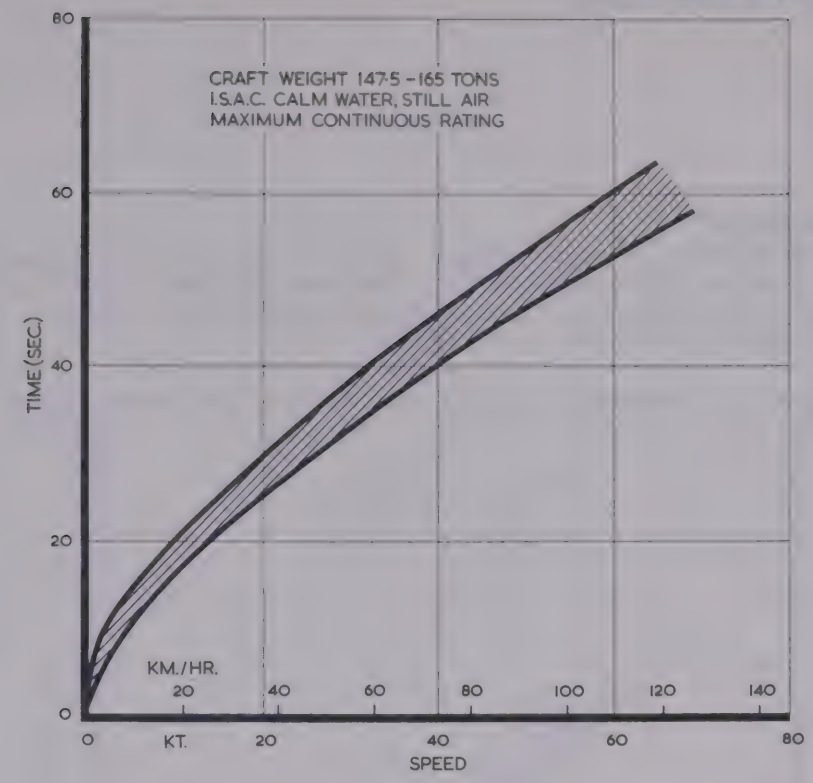
FIG. 2.8 ACCELERATION

DECELERATION

The distance curve given in fig.2.9 shows the distance required to decelerate from a given speed at the mean weight. To decelerate to zero forward speed from 50 knots requires 525 yards.

Also shown is the time required to decelerate from a given forward speed. To decelerate from 50 knots to rest takes 47 seconds at the mean weight.

The times and distances quoted apply to the case where the craft is cushion-borne throughout the deceleration manoeuvre the propellers being in reverse pitch. In an emergency, the engines may be throttled back and the skirts allowed to collapse, with a consequent reduction of the times and distances to approximately one-third of the cushion-borne values as shown on the figure.



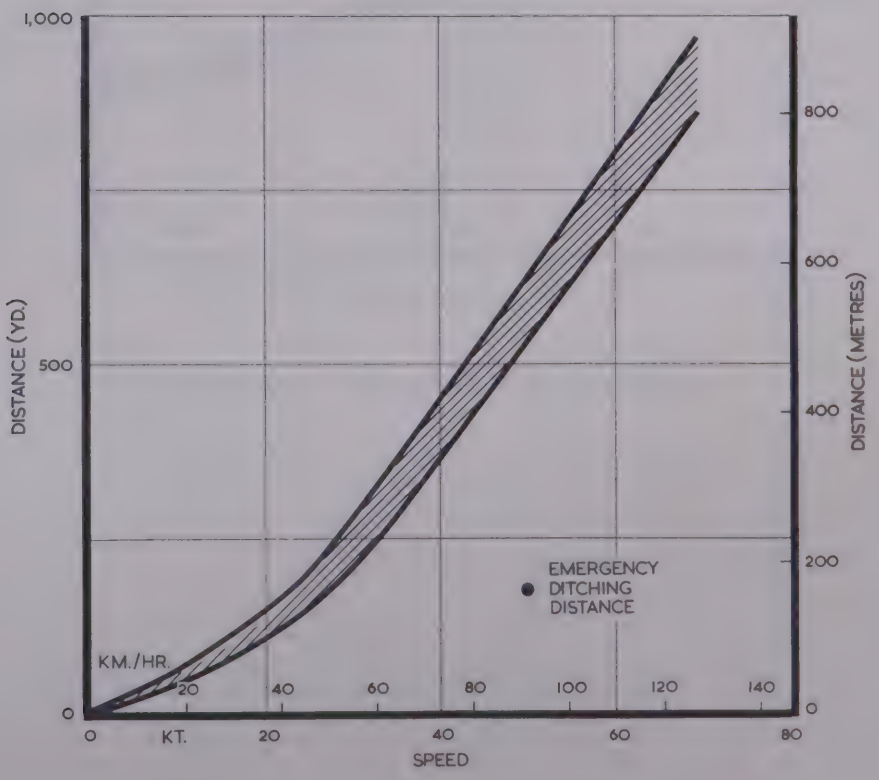


FIG. 2.9 DECELERATION

GRADIENT PERFORMANCE

The gradient performance is shown in fig.2.10 for a range of initial craft speeds at the start of a gradient of length 100 yards. The curve for which initial speed is zero indicates those gradients on which the craft can remain stationary, at the mean A.U.W. of 147·5 tons, that is 1 in 11.

For commercial operations it is recommended that the slipway gradient be not greater than 1 in 15.

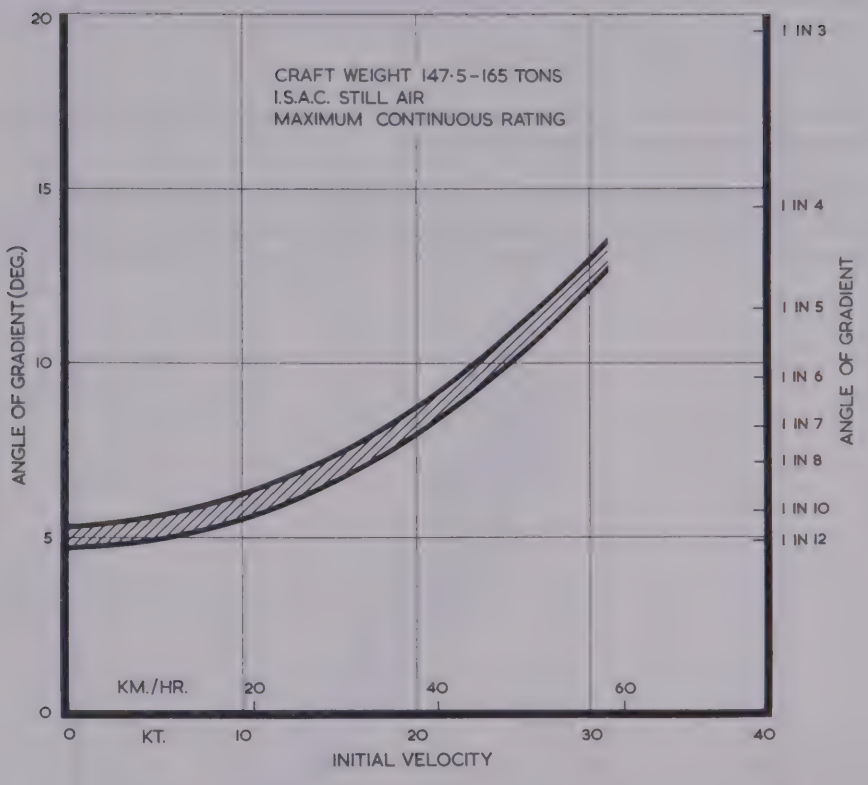


FIG. 2.10 GRADIENT PERFORMANCE

TURNING

The minimum radius of turn using the cruise engine rating is shown in fig.2.11, at the mean A.U.W. the radius of this turn is 860 yards at a speed of 40 knots.

This manoeuvre is accomplished by rotating the pylons such that the craft is yawed and rolled to give the maximum centripetal force.

The curves relate to turns made without skirt water contact. With increase in roll angle the skirts are immersed on the inside of the turn, giving a hydrodynamic force which reduces the radius of turn.

Typically a maximum rate decelerating 90^{o} turn entered at a speed of 50 knots will have a mean radius of about 500 yards.

This decelerating turn is similar to that used on SR.N6 where experience has shown that the majority of commanders prefer to decelerate before entering a turn particularly if the turn is to be made across wind from a down-wind leg.

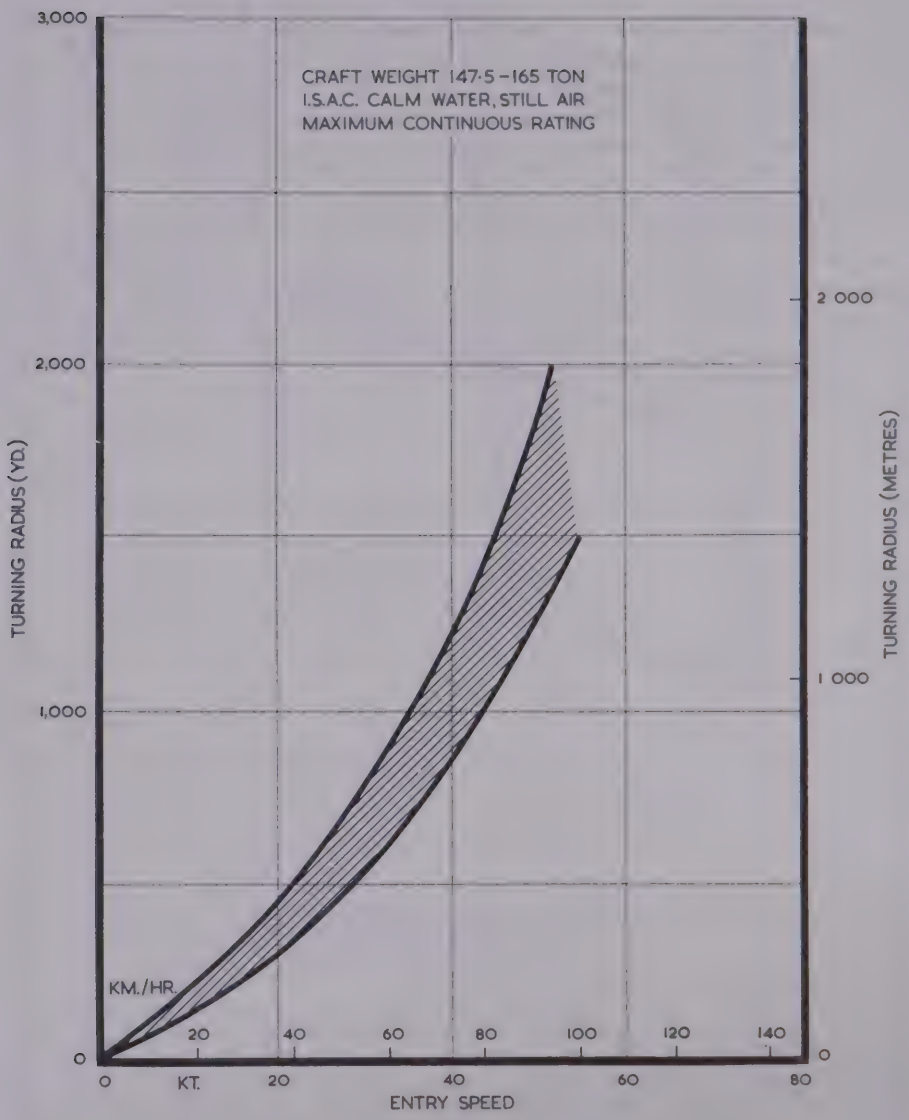


FIG. 2.11 TURNING

PAYLOAD – RANGE

Figure 2.12 shows the payload/range performance of SR.N4 in calm water, still air, I.S.A. conditions, for a range of take-off weights with a fuel load of 12 tons including a 5% reserve. Lines of constant endurance at maximum continuous power are also shown. No allowance has been made for the improvement in craft performance with reduction in weight due to fuel used. In adverse weather conditions the endurance will be the same as with a similar fuel load and engine rating, in ideal conditions the range will however be reduced in proportion to the ground speed achieved. Typically at a take-off weight of 147·5 tons with 12 tons of fuel an 18-20 knot wind will cause waves of 3-6 feet height and result in a craft service ground speed of about 40 knots giving a range of 120 n. miles.

The ultimate ferrying range of the craft, obtained by replacing all the payload by additional fuel using additional tankage up to the normal A.U.W. would be about 1,000 nautical miles in ideal conditions. However, it may well be possible to achieve ferrying ranges approaching 1,750 nautical miles by increasing the craft lift-off weight above the 185 ton overload case.

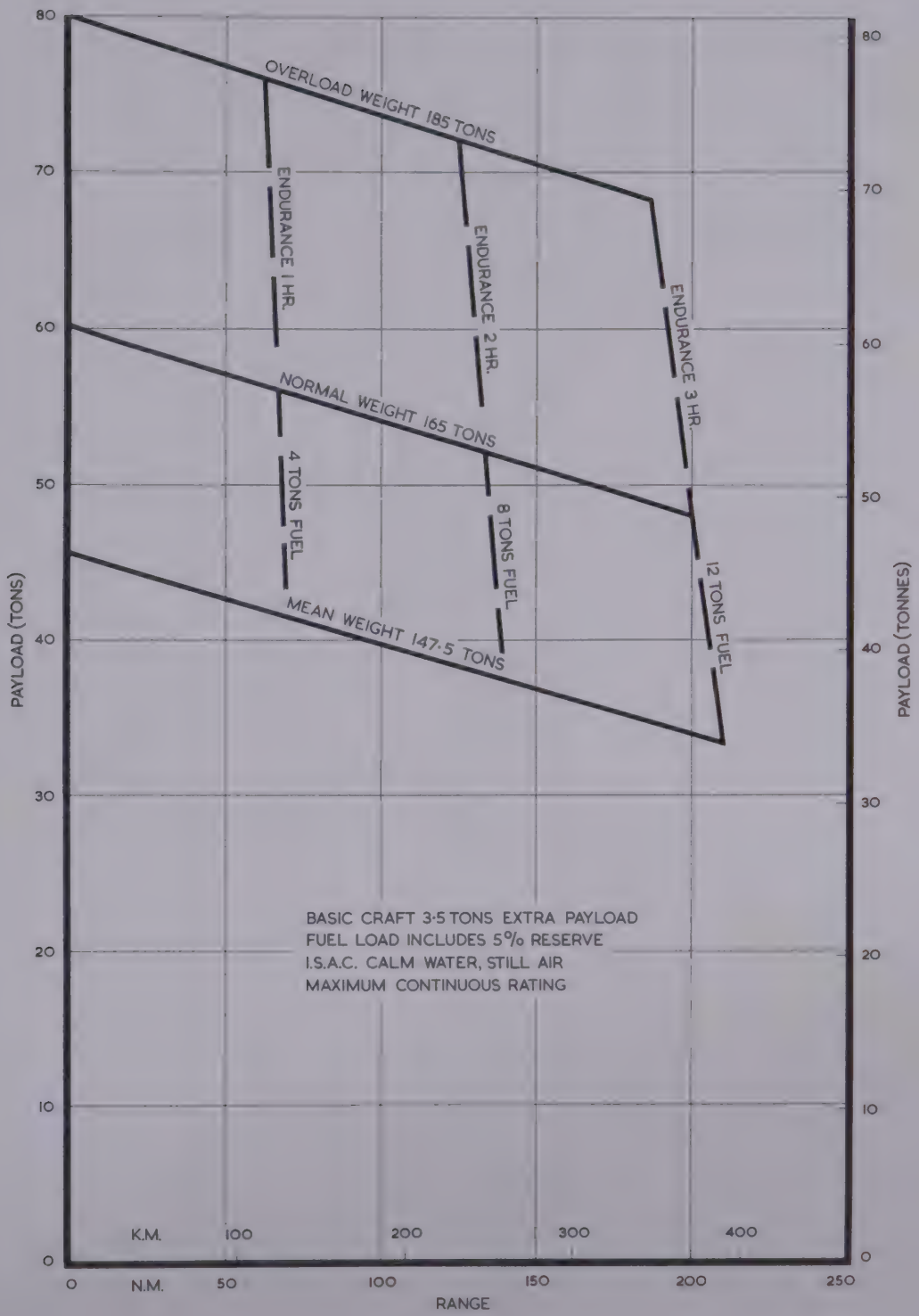


FIG. 2.12 PAYLOAD-RANGE

licensing

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Present procedure in the United Kingdom	3.1
Types of permit that are currently issued	3.1
Documentation provided	3.2
Steps to be taken by an operator	3.2

licensing

The following is an extract from British Hovercraft Corporation Ltd. Publication SP.1054 in which guidance is given on the procedure for the certification of hovercraft.

PRESENT GENERAL PROCEDURE IN THE UNITED KINGDOM

Until such time as legislation is enacted hovercraft are covered by appropriate existing transport regulations. For over-water and coastal operations, the Ministry of Aviation has assumed responsibility for purposes of certification and the Air Registration Board machinery is used. The Ministry of Aviation, in consultation with the Board of Trade, Marine Division, issue the necessary permits.

Seagoing hovercraft are treated as if they were power-driven vessels for the purposes of the international rules for collision avoidance at sea. It is hoped that international agreement on this point can be reached. Currently, general notification of the operation of hovercraft in a given area within British Territorial waters is given by means of a Notice to Mariners issued by the Board of Trade.

In general, British hovercraft are designed to the British Civil Air Cushion Vehicle Safety Requirements (B.C.A.C.V.S.R.) which have been agreed by both A.R.B. and the hovercraft industry. When they are satisfied that a craft complies with the appropriate standards of safety, to stated operational limitations, A.R.B. signify their approval of the craft by the issue of a Certificate of Construction and Performance (C.C.P.). Under A.R.B. procedures design and inspection authority can be delegated to a responsible, technical and manufacturing organization and the British Hovercraft Corporation Ltd. (B.H.C.) carries this full approval.

TYPES OF PERMIT THAT ARE CURRENTLY ISSUED

Development permit

On completion of the first craft B.H.C. apply to the Ministry of Aviation for a permit to operate on development trials in a defined testing area. No performance restrictions are placed on the craft by the Ministry and the craft is operated in accordance with the restrictions imposed by the Certificate for Flight Trials issued by B.H.C.

Demonstration permit

As development progresses, application is made for the permit to be extended to cover demonstrations to potential customers and visitors to the Company. This permit will define the standard of safety equipment required by the Ministry of Aviation and Board of Trade and performance limitations will be appropriate to the development stage reached. The technical limitations of a demonstration permit approximate to those which are applicable to a fare paying passenger operating permit but of course only apply to craft operated and maintained by B.H.C. personnel in a defined area. All production craft receive a demonstration permit prior to their despatch to an operator.

B.H.C. apply for a permit to carry fare paying passengers on a specific route as soon as a Certificate of Construction and Performance has been granted for the prototype. A regular fare paying passenger operation can be carried out under this permit and the limitations in the initial C.C.P. may later be replaced as the accumulation of the trials and operating experience show this to be possible. Thereafter the operator would be expected to obtain his own fare paying passenger permit for the particular routes on which he wishes to operate.

licensing

In the United Kingdom fare paying passenger permits are associated with an operating route and in obtaining the permit consideration is given by both the Board of Trade and the Ministry of Aviation to the sea conditions of the area, the communications required for normal operation, the life-saving equipment and the availability of rescue services. Consequently a completely open permit irrespective of the area of operation is not given at the present time.

DOCUMENTATION WHICH IS PROVIDED WITH B.H.C. HOVERCRAFT

The following documentation is included in the sale of a B.H.C. hovercraft :-

(a) Certificates of Design/Construction and Performance signed by fully approved B.H.C. personnel.

(b) A typical fare paying passenger permit for the type obtained from the Ministry of Aviation. This permit will indicate the limitations the operator may expect to be imposed.

(c) Certificate of Construction and Performance issued by A.R.B.

(d) The vehicle log book containing log cards of all significant components of the craft, such as engines, fans, propellers and other equipment.

(e) The build standard of the craft, including the approved modification schedule.

(f) A report covering the production tests of the craft to the agreed test schedule together with a certificate of flight trials.

(g) A weighing report covering the detailed weight and C.G. location of the craft.

(h) An Operator's Handbook, a Workshop Manual, and a Spares Catalogue.

It is assumed that prior to delivery of the craft an operator would have at least one pilot and possibly two engineers trained in the operation and maintenance of the craft. In initial operations these would be backed by a B.H.C. Service Engineer. B.H.C. would issue a Certificate of Competency for these personnel when they had been trained and had gathered adequate experience.

It is recommended that pilots chosen for training should have substantial marine experience together with a rudimentary knowledge of aerodynamics and aircraft control systems.

STEPS TO BE TAKEN BY AN OPERATOR

Prior to taking delivery of the craft an operator should contact the following authorities in his own country.

The equivalent of the British Ministry of Aviation or Transport to establish acceptance of British permits and certification.

The public authorities involved on a particular route.

Insurance companies.

These authorities may require an independent contact with the corresponding British authorities regarding the operation of the craft. If this is required we would recommend that they make contact with the following :-

The Operations Officer, Directorate of Flight Safety, Ministry of Aviation, Shell Mex House, Strand, London, W.C.2.

The Nautical Surveyor, Marine Safety Branch, Marine Division, Board of Trade, Surrey House, Southwark Street, London, S.E.1.

The Chief Technical Officer, Air Registration Board, Brabazon House, Redhill, Surrey.

At the present time the Operations Officer is Mr. A.O. Jones, the Nautical Surveyor is Capt. J. Batchelor and the Chief Technical Officer is Mr. W. Tye.

For general information it may be noted that the following Harbour Authorities and Town Councils are among those who have the most experience of demonstration and fare paying passenger hovercraft operations.

Harbour Authorities	Town Councils
Cowes, Isle of Wight	Ryde, Isle of Wight
Portsmouth	Cowes, Isle of Wight
Southampton	Portsmouth
Dartmouth	Weston-Super-Mare
Montreal	Penarth, South Wales

The documents contained in this guide are samples of the documentation that will be included with the craft. It has proved more than adequate for obtaining fare paying passenger permits and should form a very good basis for initial discussions with your national and local authorities.

The items on which there is likely to be the most discussion are the life-saving and emergency equipment. In this connection we would recommend that operators should familiarize themselves thoroughly with the section in the Operator's Handbook covering emergency procedures. This indicates the limits under which the craft may be anchored and towed, the procedures in the event of fire, together with all the normal operating techniques.

It would be advisable to obtain from the Post Office or appropriate authorities the radio frequencies that you will be allowed to use. In general it is necessary to have a base station at least at one end of the route and telephone communication between the bases. In addition, data should be collected on local coastguard stations and likely emergency beaching areas.

engineering

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engineering

GENERAL DESCRIPTION

The essential features in the design of the SR.N4 are the low-cost, long-life structure, and reliable mechanical components and the minimum of systems and equipment. Particular attention has been given to reducing the amount of in-situ maintenance required on a day to day basis.

To ensure high craft utilisation/serviceability the design has been tailored to a maintenance system using component replacement techniques.

The following description of the craft applies to all internal arrangements since the basic design allows for modification by either the constructor or the operator. Furnishings and equipment particular to the various layouts may be fitted as required at the change-over from one version to another.

STRUCTURE

The buoyancy tank and bow are divided into twenty-four watertight compartments in such a way that even a rip from end to end would not cause the craft to sink or overturn. The compartments of the bow structure and the inherent buoyancy of the sandwich panels used for the major horizontal surfaces have been neglected in the stability calculations, although in fact, it is quite considerable. The reserve buoyancy is over 250%, i.e. the total buoyancy available is more than 550 tons.

The concept of using standardised components throughout the structure has been carried much further in this machine than with any previous hovercraft; a basic structural grid made up of sections 94 in. long by $47\frac{1}{2}$ in. wide being used throughout the craft.

All horizontal surfaces are constructed of prefabricated sandwich panels, except for the roof which is of skin and stringer panels. Double curvature has been avoided, other than in the region of the air intakes and the bow. Figure 4.1 shows in perspective the main structural features of the craft.

The buoyancy tank is built around a grid of longitudinal and transverse frames. This grid also governs the superstructure, being maintained on the elevated passenger-carrying decks and the roof where the panels are supported by deep transverse and longitudinal frames. The buoyancy tank is joined to the roof by longitudinal walls, forming a stiff fore-and-aft structure. Lateral bending is taken mainly by the buoyancy tank.

Top and bottom surfaces of the buoyancy tank consist of sandwich construction panels bolted onto the frames, the top surface forming the vehicle deck. The upper panels over the centre 16 ft. are reinforced to carry unladen coaches or commercial vehicles up to 9 tons gross weight (maximum axle load 13,000 lb.), while the remainder is designed solely to carry cars and light vehicles (maximum axle load 4,500 lb.).

Each fan air intake is bifurcated and has an athwartships bulkhead at both front and rear, supporting a beam carrying the transmission main gearbox and the propeller pylon. The all-moving fins and rudders behind the aft pylons pivot on pintles just ahead of the rear bulkhead.

An articulated loading ramp 18 ft. wide, which can be lowered to ground level, is built into the forward end of the craft, whilst doors extending the full width of the centre deck are provided at the aft end.

Five sprung landing pads are built onto the underside of the buoyancy chamber. These are approximately $2\frac{1}{2}$ ft. in diameter and give a ground clearance of about 21 in. with the craft at normal all-up weight.

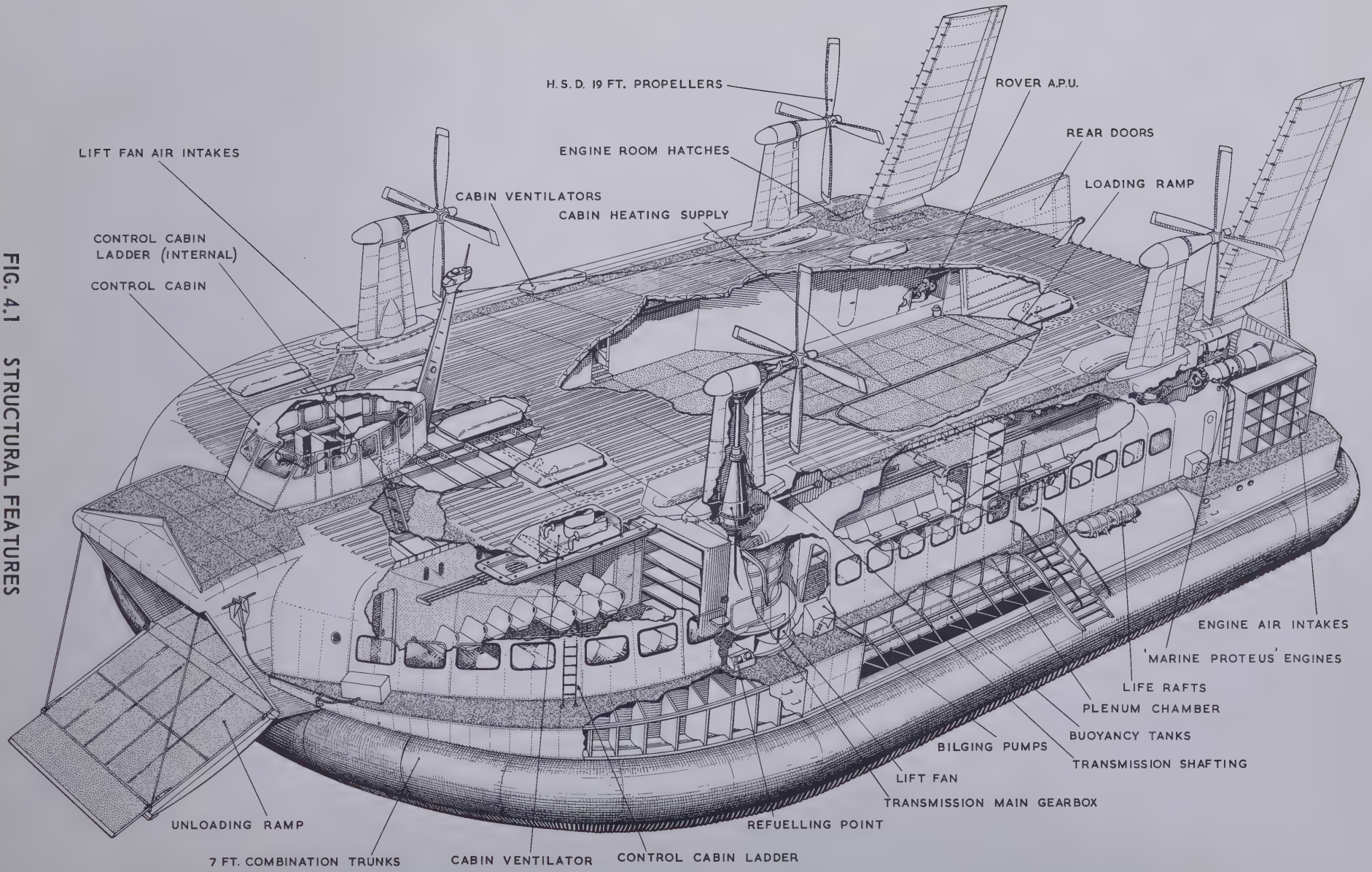


FIG. 4.1 STRUCTURAL FEATURES

FLEXIBLE TRUNKS

The system of peripheral trunks with a thwartship stability trunk, similar to that on previous B.H.C. hovercraft, has been used on SR.N4. A modification has, however, been introduced in the method by which the air is directed into the cushion. The peripheral slot used on previous hovercraft has been substituted by a system whereby the air in the side and bow trunks is directed into the cushion through a series of fingers which form the lower third of the trunks. The aft and stability trunks are similar in construction but differ from the side trunks in that the air is directed into the cushion through inverted cones.

The material used for the trunks is neoprene coated nylon fabric and although that of the fingers and cones is the same material it is of a much lighter weight. It is the greater flexibility of the lower portion of the trunks that contributes to improved control, stability and comfort.

POWER UNITS AND TRANSMISSION

The craft is powered by four Bristol Siddeley 'Marine Proteus' free turbine, turboshaft engines located in pairs at the rear of the craft on either side of the vehicle deck. Each engine is connected to one of four identical propeller/fan units, two forward and two aft, see fig.4.2. The propulsion propellers are by H.S.D. (Hawker Siddeley Dynamics), 4-bladed, variable and reversible pitch, 19 ft. (5,8 m.) diameter and the lift fans B.H.C., 12-bladed, centrifugal, 11 ft. 6 in. (3,5 m.) in diameter.

The 'Marine Proteus' develops 3,400 s.h.p. continuously and up to 4,250 s.h.p. for an emergency or for limited use in extreme weather conditions. Since the gear ratios between the engine, fan and propeller are fixed, the power distribution can be altered by varying the propeller pitch and hence changing the speed of the system, which accordingly alters the power absorbed by the fixed pitch fan. This arrangement is termed integrated lift/propulsion. The power absorbed by the fan can be varied from almost zero s.h.p. (i.e. boating with minimum power) to 2,100 s.h.p. within the propeller and engine speed limitations. A typical division on maximum cruise power would be 2,000 s.h.p. to the propeller and 1,150 s.h.p. to the fan; the remaining 250 s.h.p. can be accounted for by engine power fall-off due to the turbine r.p.m. drop, transmission losses and auxiliary drives. One of the key features of the engine room layout is the accessibility of the engine and the layout of services to the engine to facilitate an engine change in 3-4 hours.

The drive shafts from the engines consist of flanged light-alloy tubes approximately $7\frac{1}{2}$ ft. (2,28 m.) long supported by steady bearings and connected by self-aligning couplings. The shafting to the rear propeller/fan units is comparatively short, but to the forward units is approximately 60 ft. (18,27 m.).

The main gearbox of each unit comprises a spiral bevel reduction gear with outputs at the top and bottom of the box to the vertical propeller and fan drive shafts respectively. The design of the vertical shafts and couplings is similar to the main transmission shafts, except that the shafts above the main gearbox are of steel instead of light alloy to transmit the much greater torque loads to the propeller. This gearbox is equipped with a power take-off to drive an auxiliary gearbox with drives for pressure and scavenge lubricating oil pumps and also a hydraulic pump for the pylon and fin steering control. All gears are of similar design to those utilised on SR.N2, SR.N3 and SR.N5, which in turn make full use of Westland's considerable experience in helicopter gearbox design and construction.

The upper gearbox, mounted on top of the pylon, turns the propeller drive through 90°, and has a gear ratio of 1·16 : 1. This gearbox has its own self-contained lubricating system.

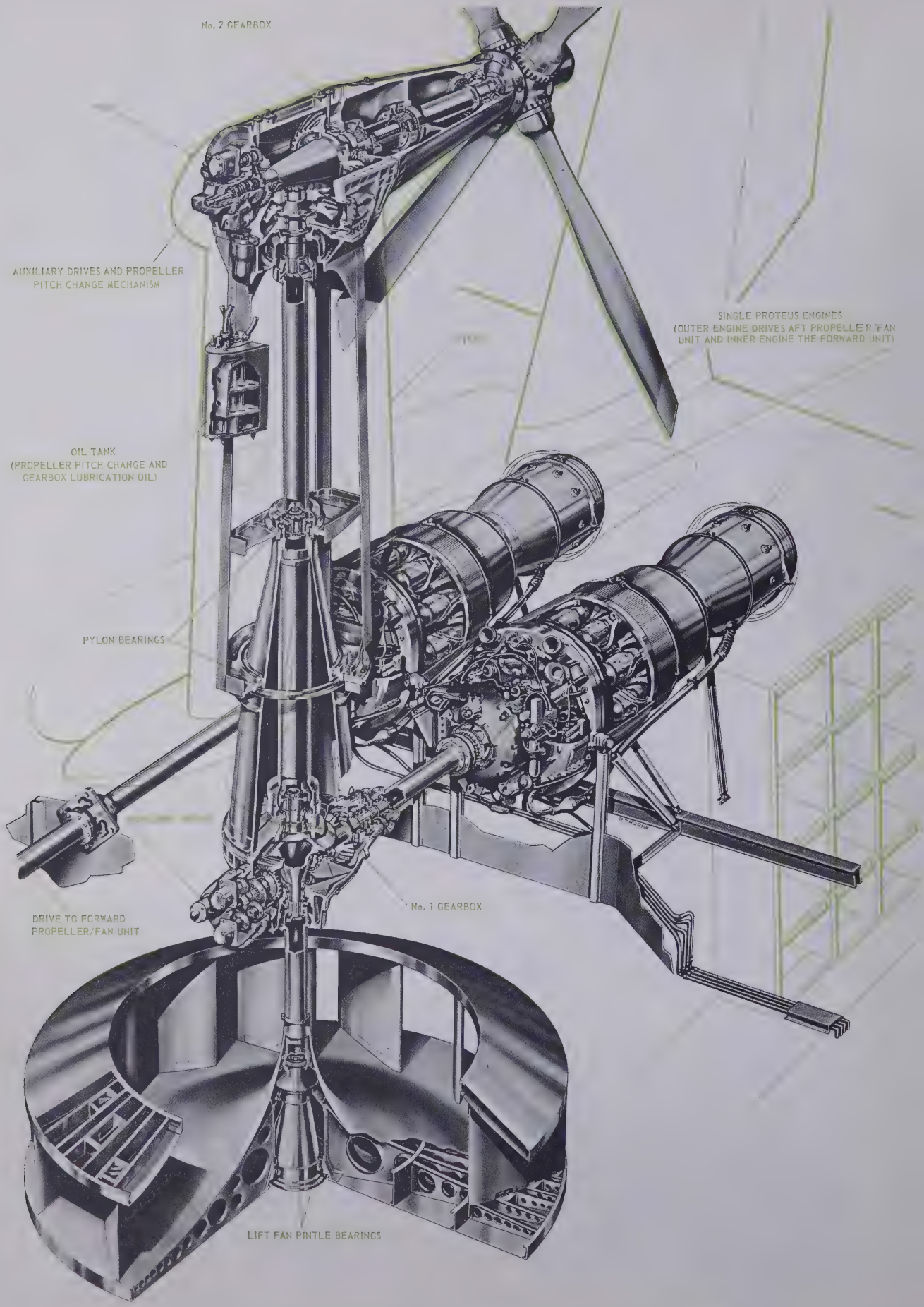

No. 2 GEARBOX
AUXILIARY DRIVES AND PROPELLER PITCH CHANGE MECHANISM
SINGLE PROTEUS ENGINES (OUTER ENGINE DRIVES AFT PROPELLER/FAN UNIT AND INNER ENGINE THE FORWARD UNIT)
OIL TANK (PROPELLER PITCH CHANGE AND GEARBOX LUBRICATION OIL)
PYLON BEARINGS
No. 1 GEARBOX
DRIVE TO FORWARD PROPELLER/FAN UNIT
LIFT FAN PINTLE BEARINGS

FIG. 4 2 ENGINE INSTALLATION, PROPELLER AND FAN DRIVES

The engines and auxiliaries are readily accessible for maintenance from inside the craft, while engines, propellers, pylons and all gearboxes can be removed for overhaul without disturbing the main structure.

The fan rotates on a pintle which is attached to the main structure. The assembly may be detached and removed inboard onto the car deck without disturbing major structure.

CONTROL SYSTEM

The craft control system is based on experience gained with the present range of B.H.C. hovercraft, especially the SR.N3, and on extensive SR.N4 model tests. It is essentially a double SR.N3 system in which the thrust lines and pitch angles of the propeller can be varied either collectively or differentially. The pylons, fins and rudders move through $\pm 35^{\circ}$, $\pm 30^{\circ}$ and $\pm 40^{\circ}$ respectively.

Demand signals for pylon and fin angles are transmitted from the commander's controls electrically. These are compared with the pylon or fin feed-back signals and the differences are amplified to actuate the hydraulic jacks mounted at the base of the pylon or fin structure. Similar electro-hydraulic signalling and feed-back systems are used to control propeller pitches. Since each hydraulic system with its associated electrical signalling system is completely independent, adequate control can be maintained in the event of any three simultaneous failures.

The commander's controls include a rudder bar for steering the craft and achieves this by pivoting the propeller pylons differentially, for example, if the right foot is moved forward the forward pylons move clockwise, viewed from above, and the aft pylons and the fins move anti-clockwise thus producing a turning moment to starboard. Rudder bar movement also varies the propeller blade angles differentially so as to increase the craft's turning moment produced by pylon and fin movement. The foregoing applies with positive thrust on the propellers, but if negative thrust is applied, as in the case of using the propellers for braking, the pylons and fins are automatically turned to apposing angles thus maintaining the turn. A wheel mounted on a control column enables the commander to move the pylons and fins in unison to produce a drift to either port or starboard as required. Collective variation of the propeller pitch angles and hence control of the distribution of power between propellers and fans, is by fore-and-aft movement of the control wheel, used in conjunction with the engine throttle levers. The control system is shown diagrammatically in fig.4.3. The groups of pick-offs for each signalling system are shown at each of the commander's controls. The electrical circuits are fed from a D.C. supply and can continue to operate in the unlikely event of a complete generation failure.

A layout of the control cabin is shown in fig.4.4. The basic manning requirement is for a commander, an engineer/radio operator and a radar operator/navigator. A seat is provided for a fourth crew member or a crew member in training. The remainder of the crew who are concerned with passenger service or car handling are located in the main cabins. The arrangement may be modified to suit individual operator's requirements.

Access to the control cabin is achieved in two ways. The normal method, when the cars are arranged in four lanes, is by a hatch in the cabin floor reached by a ladder from the car deck. When heavy vehicles are carried on the centre lane, or for some other reason the ladder has to be retracted, a door in the port side of the passenger cabin gives access to a ladder leading onto the main cabin roof, from which an entrance door into the control cabin can be reached.

FUEL SYSTEM

The fuel system shown in fig. 4.5 and 4.6 has been designed for maximum reliability in the event of the failure of a pump or similar component and has been greatly influenced by the fact that it serves as a ballast system and by the necessity to keep the main tanks outside the area of the vehicle deck. The latter requirement arose from detail safety considerations such as running the system pipes along the outside of the buoyancy tank away from the top surface where they might be damaged by debris ingested by the fan. Another safety feature is that the tanks themselves are of the bag type contained within fuel-tight compartments.

The fuel is contained in four groups of three tanks, giving a total usable capacity of 4,500 gallons (16 tons).

Each group of tanks is fitted with three pumps, an engine feed pump and two larger pumps which transfer fuel in the event of a main feed pump failure, or for trimming purposes. The large transfer pumps are designed to be able to transfer 4 tons of fuel longitudinally or laterally in $5\frac{1}{2}$ minutes.

In the event of failure of any one engine feed pump, the supply to the associated engine is maintained automatically its supply pipe being connected to that of the other engine on that side of the craft. This would create a condition where two engines were being supplied from the same source. Two alternative means are provided to prevent this, either fuel can be transferred into the tank, or the transfer pumps in the relevant tank can be used in place of the failed pump, after opening a cock in the feed line.

Transfer of fuel is an automatic operation in so far as the associated transfer cock, the transfer pumps in the tanks from which the fuel is to be transferred, and the refuelling valve in the receiving tank are operated simultaneously by the closing of a switch after the required sequence has been selected.

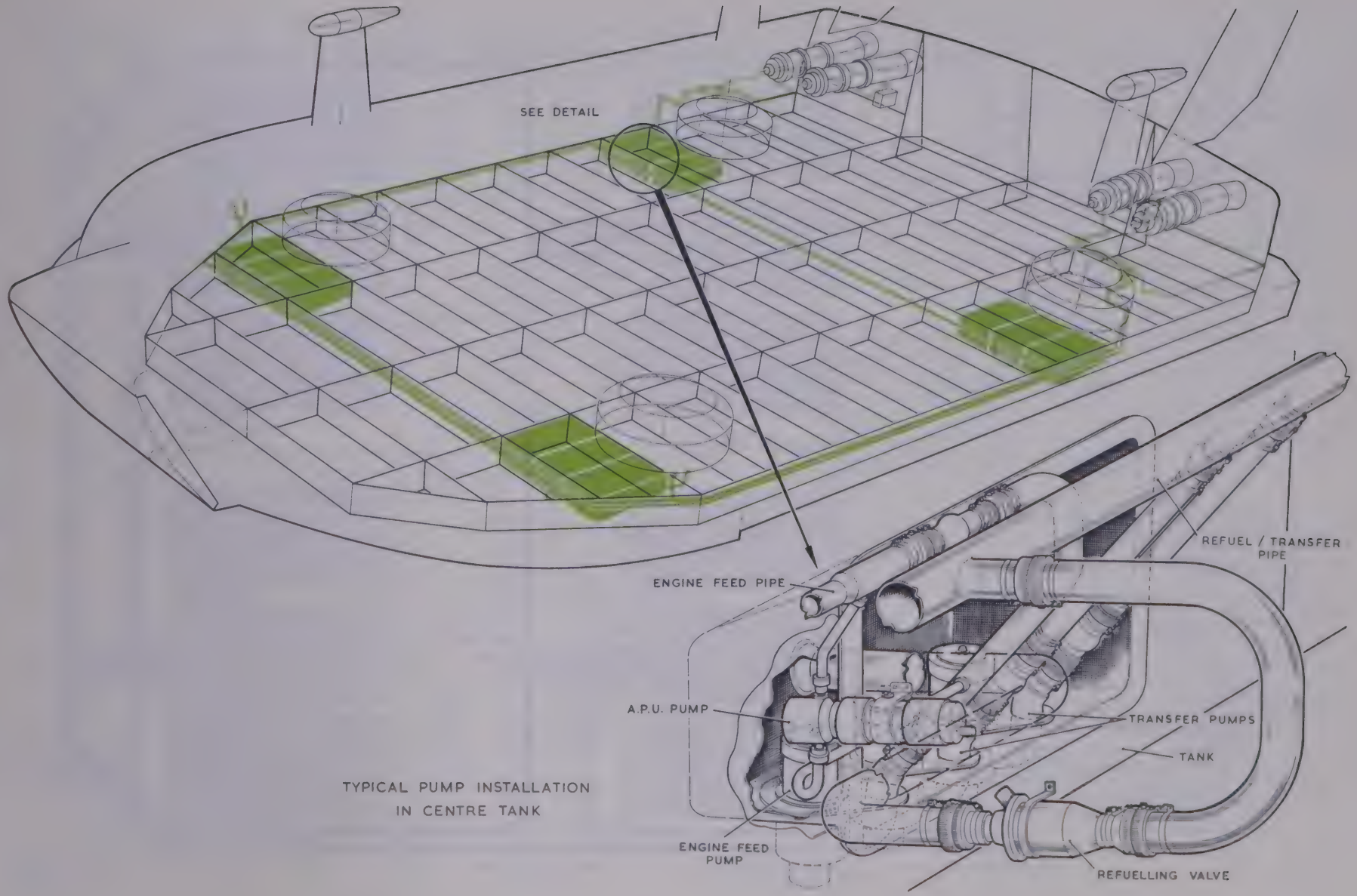
Fuel is supplied to the auxiliary power units from the main tanks by a D.C pump which can be operated from the main batteries enabling the A.P.Us to be started before starting the main engines.

A pressure refuelling point is provided on either side of the craft, each point being designed for a refuelling rate of 300 gallons per minute. If both refuelling points are used simultaneously the craft can 'take on' a normal fuel load in approximately six minutes.

HYDRAULIC SYSTEMS

The arrangement of the hydraulic systems, as shown on fig. 4.7 and 4.8, gives a very high degree of safety over the control of the craft, since the failure of any one component cannot affect another system. Long pipelines which would normally be associated with a craft of this size have been avoided.

There are eight separate hydraulic systems. Of these, two are electro-hydraulic, one for the actuation of the bow ramp, starboard fan intake shutters and passenger stairs, and the other for operating the rear doors and the port fan intake shutters and passenger steps. In addition each pylon has its own self-contained system driven from its main gearbox comprising pump, filter, servo valves, jacks and tanks, while the fins are operated by two similar systems. Four feed pumps, one on each of the propeller gearboxes, supply oil pressure to actuate the propeller pitch change mechanism. A hydraulic 'parking' brake is provided for each transmission system and are manually operated by levers adjacent to each fan.



TYPICAL PUMP INSTALLATION IN CENTRE TANK

FIG. 4.5 FUEL SYSTEM

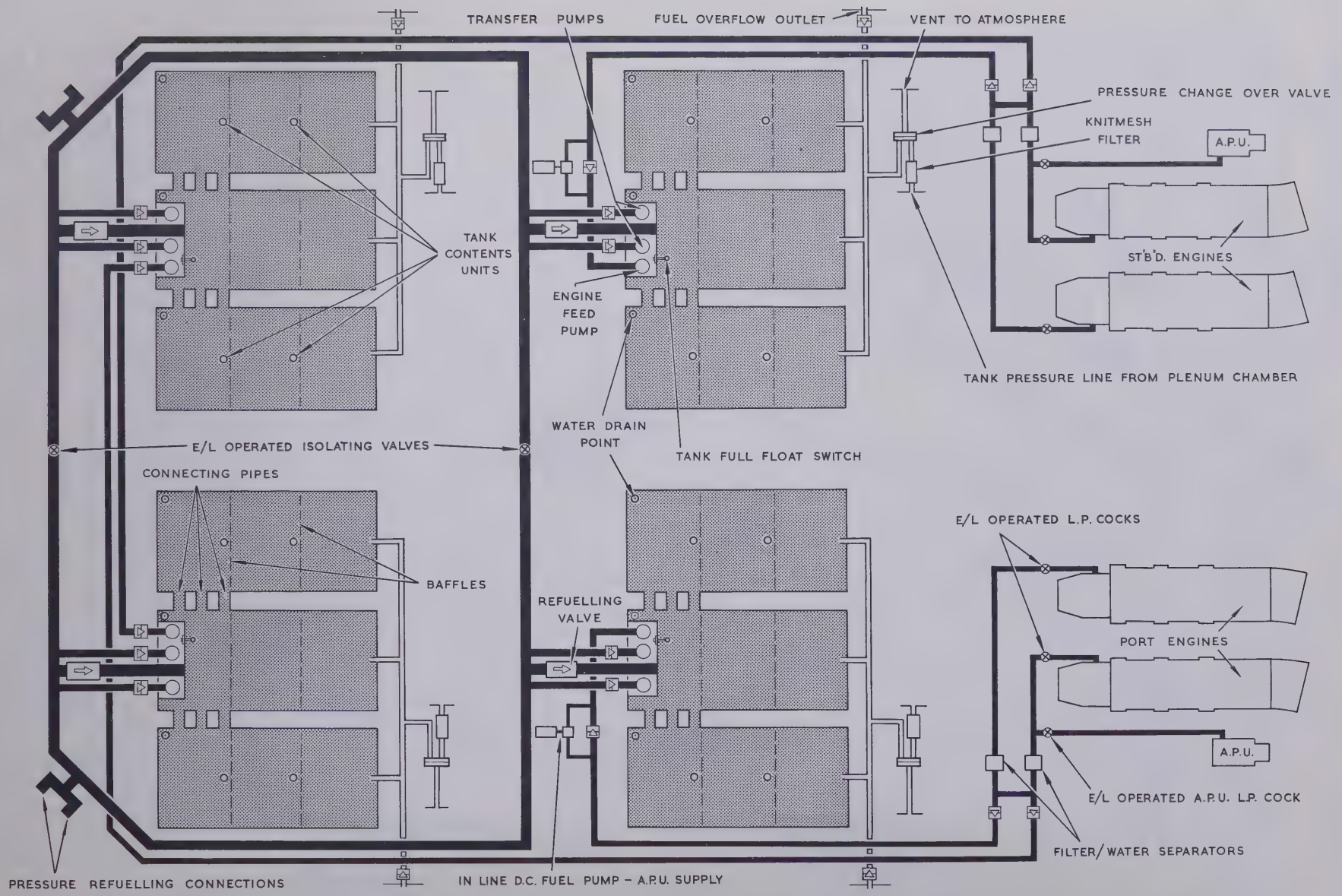


FIG. 4.6 FUEL SYSTEM DIAGRAM

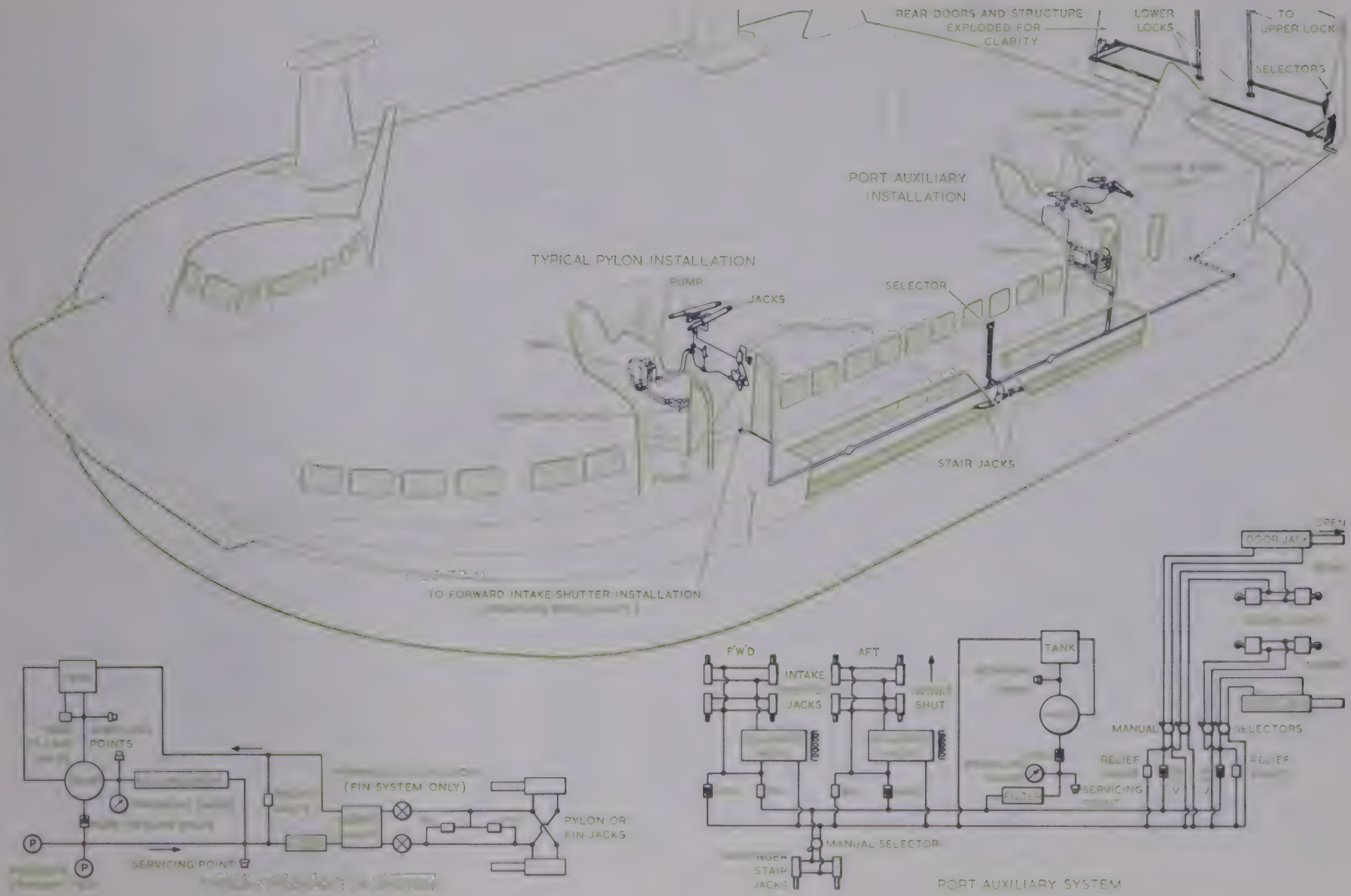


FIG. 4.7 HYDRAULIC SYSTEMS – 1

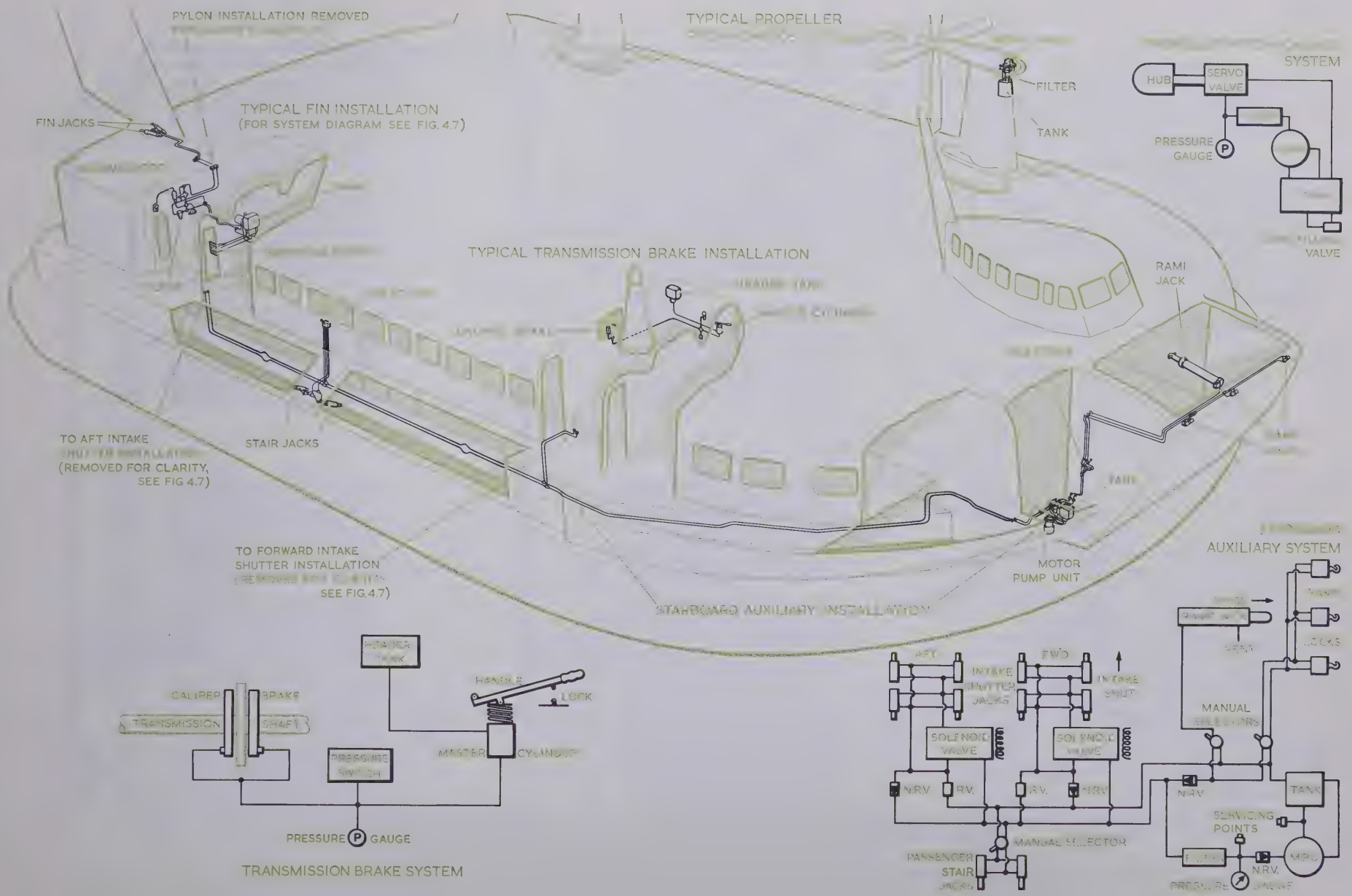


FIG. 4.8 HYDRAULIC SYSTEMS – 2

LUBRICATION SYSTEM

All the engines and gearboxes are independently pressure lubricated. The oil is cooled by air from the plenum chambers and the coolers for the engines and aft main gearboxes are located on either side of the craft just forward of the engine air intake filters, while the coolers for the forward main gearboxes are in the outside wall of the plenum chamber below the forward crew doors. The oil is circulated by feed and scavenge pumps, each system having its own tank and filters. The lubrication system for each propeller gearbox is self-contained in the nacelle and pylon and consists only of a tank, feed pump and sump. The tank is integral with the pylon and relies on the air flow over the nacelle and pylon for heat dissipation.

From the foregoing and fig.4.9, it will be clear that a failure in any lubrication system only affects its associated component and will, at the worst, cause a shut down of only one engine/propeller/fan unit.

ELECTRICAL SYSTEM

Electrical power is supplied by two turbo-alternator sets driven by Rover 1S/90 gas turbines (A.P.Us). Each A.P.U. is housed in a bay, one in each of the port and starboard engine rooms. Main generation is held constant at 208 volts 400 c/s, 3 phase. Two brushless alternators of the rotating rectifier type, are provided to ensure that an adequate electrical supply will be maintained in the event of an alternator failure. Each alternator supplies power to a separate A.C. busbar, thus avoiding engine regulation to close limits that is needed for parallel operation of alternators; a change-over system is provided to enable each alternator to supply to either busbar.

Before starting the main engines, one of the A.P.Us must be started from the two 28V batteries. This provides A.C. power, which is rectified using full wave rectifiers to produce a substantial D.C. supply capable of operating the electrical starters on the 'Proteus' engines.

A large proportion of the generated A.C. supply is consumed by the ventilating fans and the lighting loads. In addition a transformer/rectifier unit is used to supply essential but minor D.C. loads such as fire detection and extinguishing, control system and battery charging.

Adequate means of protection for all loads and circuits are incorporated in the system to ensure 'fail safe' operation and all the equipment used is of proven reliability.

The basic circuit is shown in a simplified form in fig.4.10.

HEATING AND VENTILATING SYSTEMS

A duct directed into the eye of each lifting fan withdraws air from the car deck and, as both the passenger cabins and control cabin are vented into the car deck, the complete craft is ventilated by this source. See fig.4.11.

Fresh air is introduced into the car deck and passenger cabins through a series of ventilators in the roof while the control cabin is ventilated through its floor. In each ventilator an electric fan has been installed to boost the supply of fresh air into the craft and it is at these points that hot air, bled from two of the main engine compressors, is introduced.

FIRE PRECAUTIONS

Steel-lined fireproof bulkheads isolate the engine rooms, each of which is divided by a thwartship firewall at the forward end. This again is divided into two zones to isolate each engine. The major part of each engine is encased in a fireproof jacket and the intervening space thus formed is fed with air for cooling the engine and the exhaust ducts. A fire warning system is provided together with double-headed extinguisher bottles enabling single or double shots to be fired into any one of the engine bays.

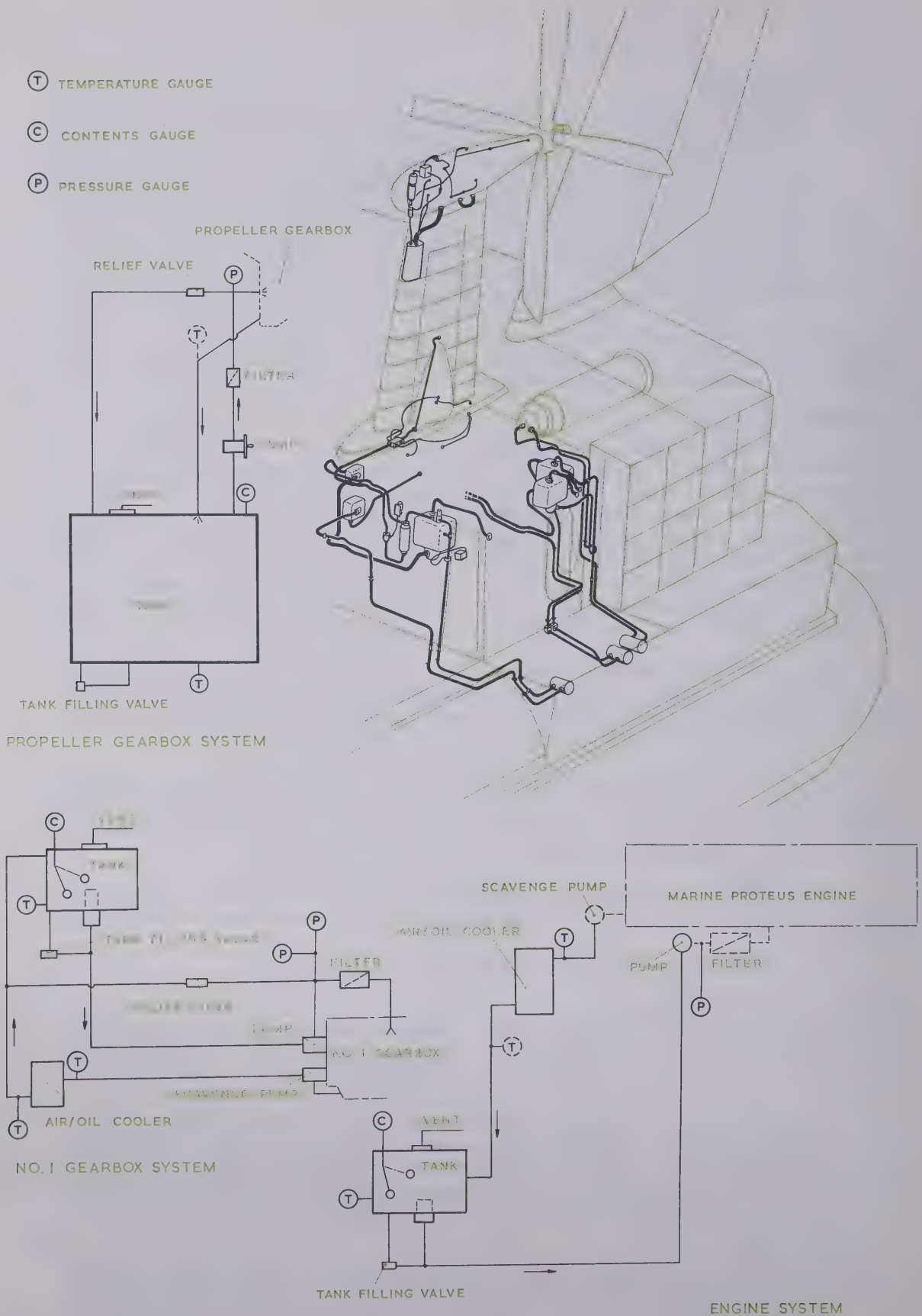


FIG. 4.9 LUBRICATION SYSTEMS

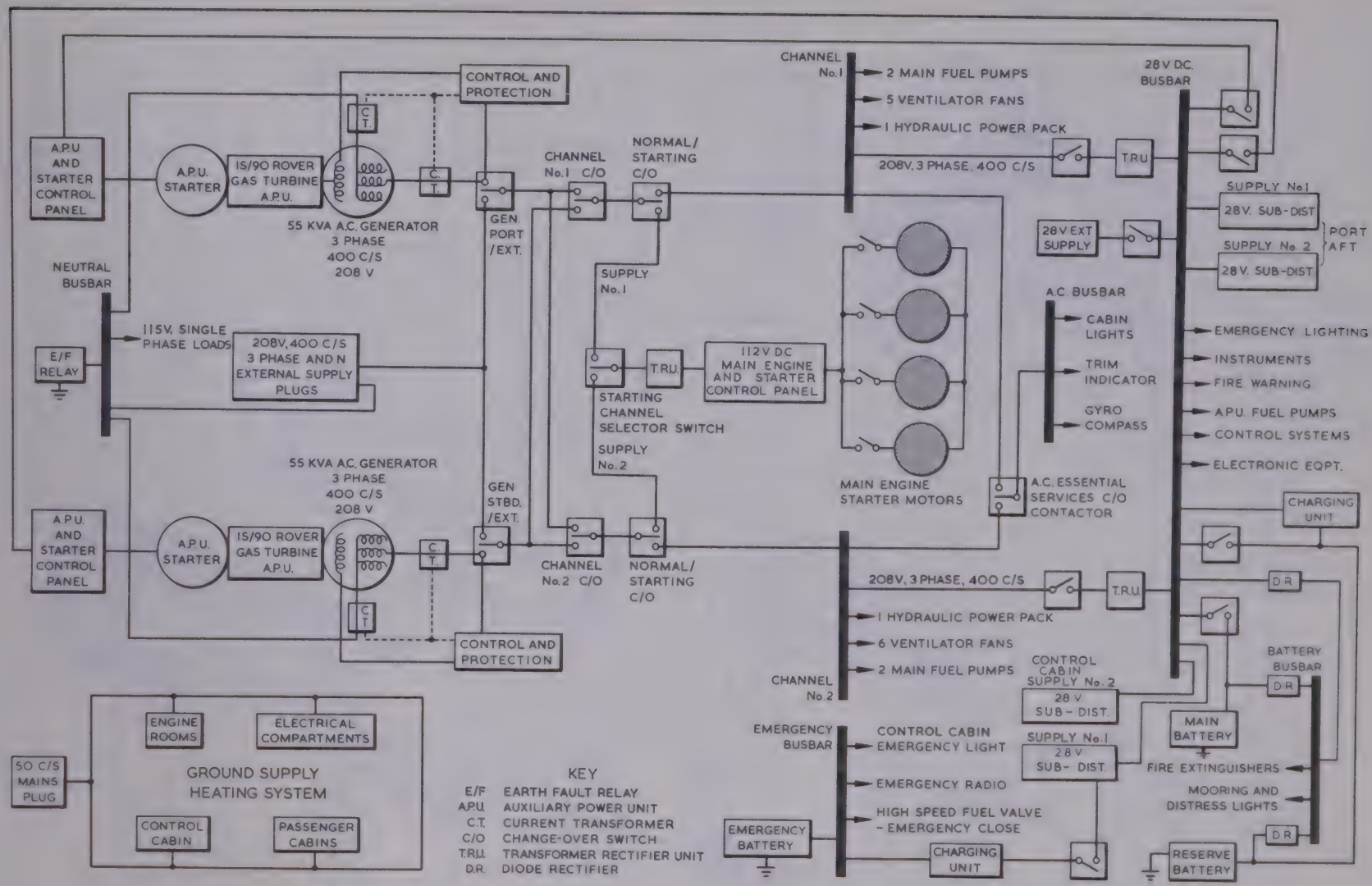


FIG. 4.10 DIAGRAM OF ELECTRICAL SYSTEM

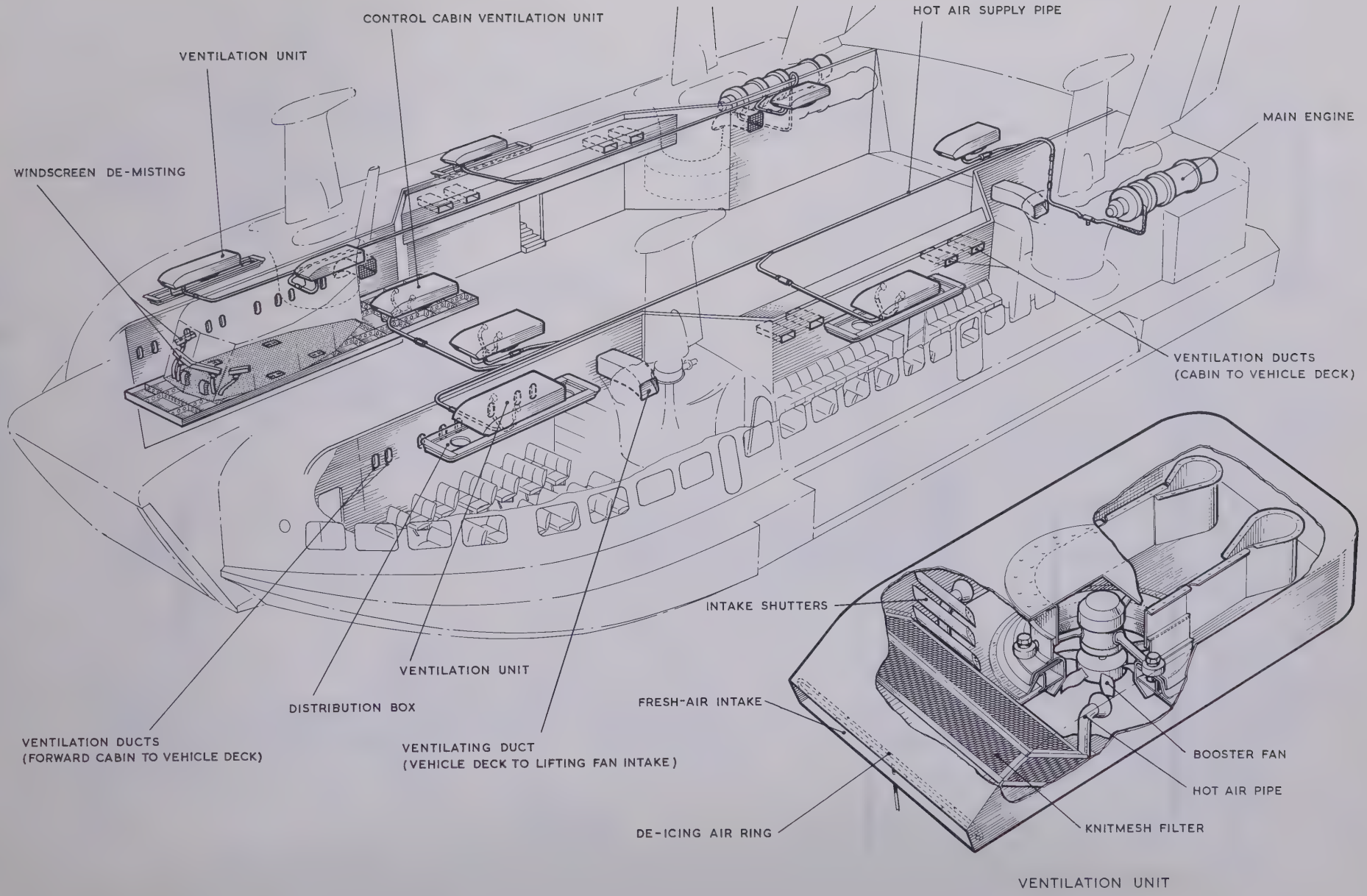


FIG. 4.11 HEATING AND VENTILATING SYSTEMS

Each A.P.U. is completely isolated by steel firewalls and the compartment has its own firewire warning and fire extinguishing systems. A flame trap in the combustion air intake prevents a fire in the A.P.U. compartment spreading to the main engine room.

The compartments housing the electrical equipment are fitted with smoke detectors with associated warning lamps in the control cabin.

Hand fire extinguishers are provided at strategic points throughout the craft both in the passenger cabins and the car deck.

BILGING SYSTEM

The craft has a self-contained bilging system which enables each compartment of the buoyancy tank to be bilged independently. See fig.4.12. Fixed pipes run from the bottom of each compartment to one of four externally-mounted collector boxes mounted two forward and two aft, on the skirt support structure. An electrically-driven pump in each collector box, in conjunction with selector cocks enables four compartments to be bilged simultaneously. Each system is independently controlled from within the craft enabling the buoyancy compartments to be bilged whilst the craft is in operation and without the aid of ground equipment.

EMERGENCY EQUIPMENT

The number of liferafts carried will depend on the type of seating layout. The basic craft is provided with 184 lifejackets and also eight 27-seat inflatable liferafts and two lifebelts stowed externally on the decks, adjacent to the passenger doors. Anchors, towing bridle, flares, first-aid kit, emergency tool kit etc. are also provided. A full list of equipment is listed elsewhere in this document.

NAVIGATION AND COMMUNICATION EQUIPMENT

The control cabin has been placed above the general level to ensure maximum all-round normal vision, but for operation at night or in poor visibility the craft will be equipped with standard ship's radar and, where applicable, a Decca navigator. If the radar is of the true-motion type, then an accurate water speed measuring device such as 'doppler' equipment must be fitted. The standard radio equipment for communication will be the V.H.F. - FM (Marine) type.

Normal navigation lights, together with a flashing amber identification light, are fitted as standard.

NOISE

Special consideration has been given to the reduction of noise in order to make the SR.N4 considerably quieter, both externally and internally, than its smaller predecessors. The problem has been evaluated using information derived from the following sources :-

(1) Extensive noise measurements on existing hovercraft.

(2) Information supplied by B.O.A.C. regarding noise measurements on 'Britannia' aircraft. (Four Bristol Siddeley 'Proteus' engines driving propellers).

(3) Measurements of noise from marine craft and stand-by generating sets powered by Bristol Siddeley 'Marine Proteus' engines.

(4) Theoretical considerations, particularly with regard to propeller noise.

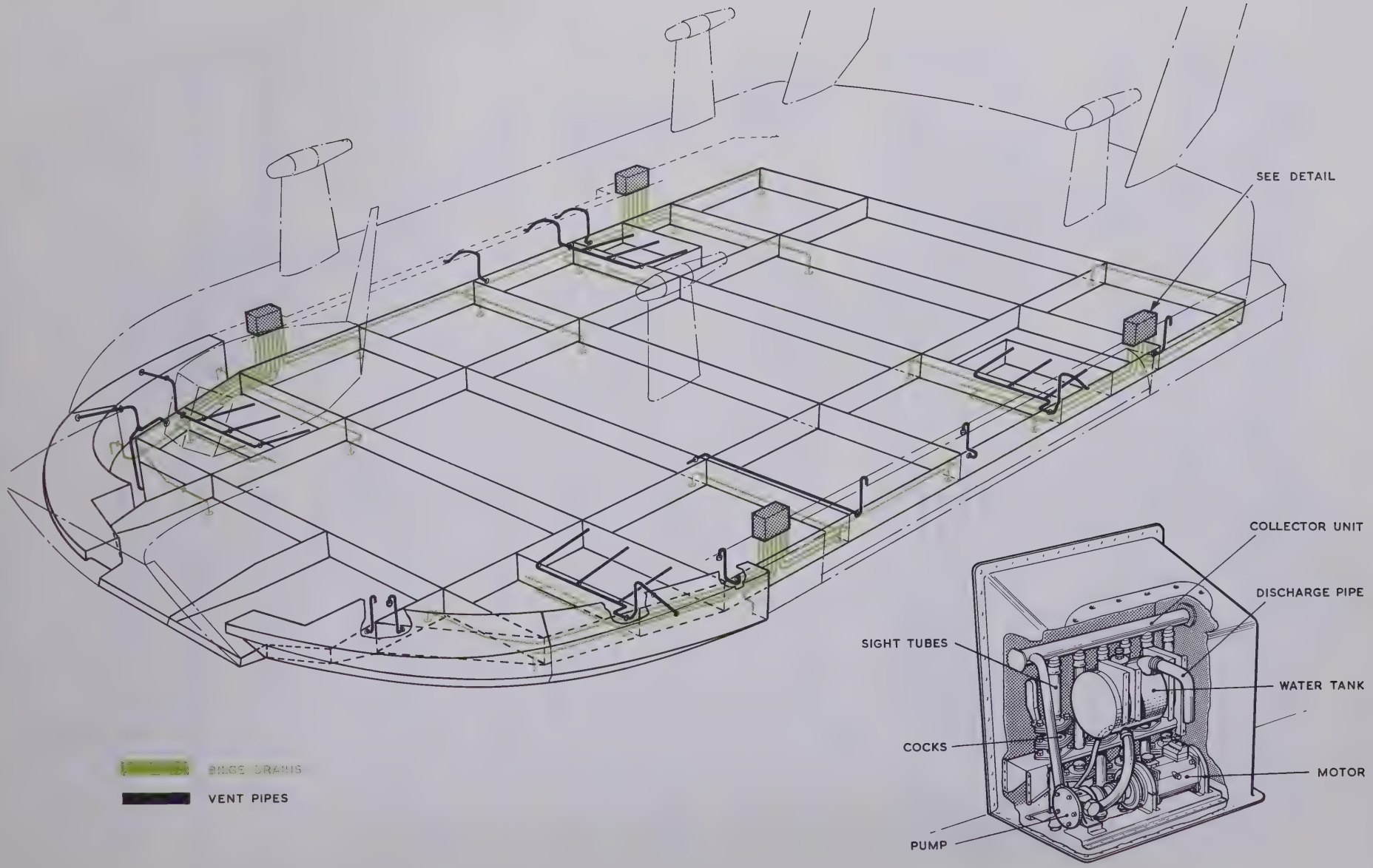


FIG. 4.12 BILGING SYSTEM

External noise is generated primarily by the propellers, lifting fans and engines. In the case of propeller noise a significant reduction has been achieved by keeping the tip speed down to a maximum of approximately Mach 0·6, as compared with the 0·8 to 0·85 maximum attained by the propellers of previous craft. This gives a reduction of the order of 25 dBA per unit at the appropriate maximum input power. Fan noise has been kept down by having as low a rotational speed as possible. Measurements on marine craft powered by 'Proteus' engines have shown that exhaust noise is relatively unimportant.

A substantial reduction in overall noise has been achieved and at a distance of 500 ft. this is of the order of 15 dBA less than that of existing hovercraft. The overall design of the craft together with the suggested terminal layout reduces the manoeuvring time and in consequence the turn-round time to a minimum.

With regard to internal noise, particular attention has been given to this problem in planning the basic layout of the craft. The engines are located in isolated compartments at the stern and due consideration has been given to other important noise sources such as the propellers, lifting fans and main gearbox units. Full use has been made of experience gained from existing craft in designing the soundproofing arrangements for the SR.N4.

SERVICING REQUIREMENTS

The SR.N4 has been designed with ease of servicing in mind and all components and systems are easily accessible for maintenance and replacement purposes.

For routine maintenance the craft can be parked on ground capable of taking loads from the landing pads. In the case of level ground where all five pads are in contact, the ground pressure from about 4·5 tons/sq.ft. (48,4 tons/sq.m.) to 7 tons/sq.ft. (75 tons/sq.m.) for unladen and maximum weights respectively.

For inspection and maintenance of the bottom area and the skirts the craft may be lifted by three pairs of jacks housed in tubular 'legs' on which the craft can stand for indefinite periods. These legs are ground equipment and are fitted through special apertures in the buoyancy tank. The lifting jacks are operated by a portable electro-hydraulic pack powered from a ground supply. Valves on the supply lines of the three centre jacks enable the operator to raise the craft in a level and controlled manner.

A mobile crane is the only large piece of equipment required for major servicing operations, for example, the removal of a propeller, pylon, fin, gearbox or engine. A suitable crane would have a jib length of about 50 ft. (15 metres) and a load capacity of approx. 5 tons at 10 ft. (3,05 m.) radius.

Full provision is made for periodic engine washing and the necessary piping and spray rings are built into the craft for this purpose. Ground connections for an engine washing trolley are provided.

REPLACEMENT OF LIFED COMPONENTS

Components with fixed overhaul or retirement lives, such as the engines, gearboxes and other transmission components will be changed as necessary, time expired units being usually returned to the manufacturer for overhaul. It is anticipated that the overhaul life of the engine will be at least 2,000 hours, and that of the transmission components 2,000 hours when the SR.N4 is first introduced into service. These times will be increased as experience is gained in service.

operating requirements

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	fig.
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operating requirements

While the layout of any hoverport will depend very much on the type and frequency of service to be operated and on the site available, certain minimum requirements must be met to permit the safe and efficient operation of the SR.N4; this section is a guide to these requirements.

A terminal can be built in any area having a suitably sheltered shore and in reasonable proximity to road and rail services; deep water is not a necessity. Such a base will often give much greater freedom of operation than one built within an existing harbour; these are usually busy, have narrow entrances and are located in congested areas which incur delays when leaving by road. The main advantage of using an existing port would seem to be the availability of local transport for a 'Domestic' passenger service or of Customs and other facilities on 'international' routes, both can usually be provided afresh for a service which involves a reasonable flow of traffic. The least acceptable method of handling a hovercraft is in the displacement condition, using existing quays. However, it is expected that trial, temporary or low frequency operation may have to be operated in this manner and therefore means of doing so have been included in this section.

GENERAL REQUIREMENTS

The SR.N4 has been specifically designed to permit a rapid turn-round as this is particularly important on short routes. From the description of the craft it will be clear that vehicles can drive straight off as soon as the power-operated bow ramp is lowered, while passengers leave simultaneously by the integral passenger steps on either side of the craft. During this period a mobile ramp can be brought up to the wide stern doors, permitting cars to drive on easily and quickly as soon as the deck is clear. To allow these features to be used to the full, hoverports must be designed to provide easy access in all weathers and let the craft come to rest without the need for precise manoeuvring. In addition, since a turn of 180° is likely to take from 2 - 3 minutes, and because such 'static' manoeuvres generate the maximum amount of noise and fumes and cause the maximum of skirt wear, the use of a single slipway is not recommended unless a turning aid such as a turntable or 'land tugs' can be provided to rotate the craft quickly while at rest or operating on minimum power. All hoverports must be designed to minimise the effect of spray and dust generated on the approach, to protect passengers and cars, provide ease of marshalling and handling both incoming and outgoing traffic and supply means of fuelling, replenishing stores and cleaning the craft. The latter will initially be done from wheeled vehicles such as bowsers, toilet and cabin cleansing trucks and, where needed, trucks for replenishing duty-free goods and refreshments. At a later stage bowsers and cleansing trucks would be replaced by fixed installations - the craft at a busy hoverport, handling up to fifteen SR.N4s per hour, could easily consume up to an average of 1 ton of fuel per minute from the supply system. Additional attractions such as restaurants, banks, left luggage depositories, waiting-rooms and 'visitors' galleries and car-parks could be added to the larger bases as the service builds up.

Operation in bad weather and during hours of darkness can be assisted by a number of aids. Radio communication is, of course, essential and the SR.N4 will, in itself, be fitted with radar and other navigational aids. If essential to keep services running in very bad visibility it may be possible to utilise devices such as surveillance radar or radio beacons to assist in the final approach to the base and leader cables to permit the craft to climb the ramp and manoeuvre when almost 'blind'. Under normal conditions approach buoys, ramp centreline markers, guide lights and radar reflectors will be required, various forms of which are being tried in connection with SR.N6 services. For night operations the apron must be flood-lit as soon as the craft comes to rest to give free movement of passengers and cars without fear of accident.

operating requirements

During normal operations craft will not be expected to alight on approach ramps or the greater part of the apron. Therefore, although these surfaces must be given a smooth surface to reduce skirt wear and dust generation and to allow water to rapidly drain off, they need only be strong enough to support the craft in an emergency, some damage from landing pad loads being permissible. The normal alighting area must, of course, be designed to take repeated landings of the craft, the normal load per landing pad ($2\frac{1}{2}$ ft. diameter) being up to 33 tons on level ground or 75 tons on uneven ground (with craft balanced on three pads). The design of the approach ramps is more likely to be dictated by tides and storms rather than the need to support the hovercraft.

It has been found that the noise that is apparent from a hoverport is very much affected by the shape of the surrounding land and the direction of the prevailing wind. If a terminal must be built close to a residential area consideration should be given to screening the noise as much as possible from the landward side and to avoiding enclosed areas facing into wind. Twin slipway hoverports, which demand very little manoeuvring, are particularly recommended since the period of peak noise is then reduced to the very minimum. The recommended angle between the ramps is 120° as this means that one ramp will always be available where the wind is neither directly astern or on the beam and the turn angle is only 60°. However, where the site demands that the included angle is less than 120° this is acceptable down to say 80°; thereafter a wide single ramp should be used.

Maintenance areas have been shown on the larger hoverports for the routine maintenance which would include engine and propeller changing and skirt repair as well as equipment servicing and structural repairs and maintenance. These maintenance areas must have a fully equipped workshop and be equipped with power supplies, water, lifting gear, spares, tools and any special equipment required for day by day servicing. While full overhauls or refurbishings could be carried out at these sites, perhaps with the aid of specialist engineers, for major repair the craft may need to be sent back to the manufacturer or to specialised maintenance organisations, and therefore proposals for the design of a specialised maintenance base are not given.

Based on a standard method of calculation, assuming British cost levels and that the aprons and ramps can be of a 'filled' rather than a 'piled' construction, the approximate cost of the hoverports (including buildings) shown in figs. 5.1, 5.2, and 5.3 would be £100,000, £400,000 and £500,000 - £600,000 respectively. However, these figures can only be taken as an indication of the relative values, actual costs would depend on the site chosen and the degree of complexity thought necessary at the start of a service as well as differences in contractors' methods and charges.

RECOMMENDED TYPES OF HOVERPORT

Minimum requirements for domestic services

Figure 5.1 shows the type of hoverport recommended for low frequency 'Domestic' Services where cost must be kept to a minimum, delays due to bad weather can be tolerated and the area is not particularly sensitive to noise. It covers an area approximately 400 ft. square (4 acres) and has the bare minimum of equipment. The single ramp has been made wide enough to give some tolerance in the direction of approach and to permit the craft to leave after turning through rather less than 180°. The slope of the ramp is recommended as 1 in 15 but this can be reduced to 1 in 12 if required. The length of ramp shown can only be achieved in areas with a low tidal range or where the natural beach can be used as the main approach, as shown on the diagram. The apron area on this and on all other hoverports should

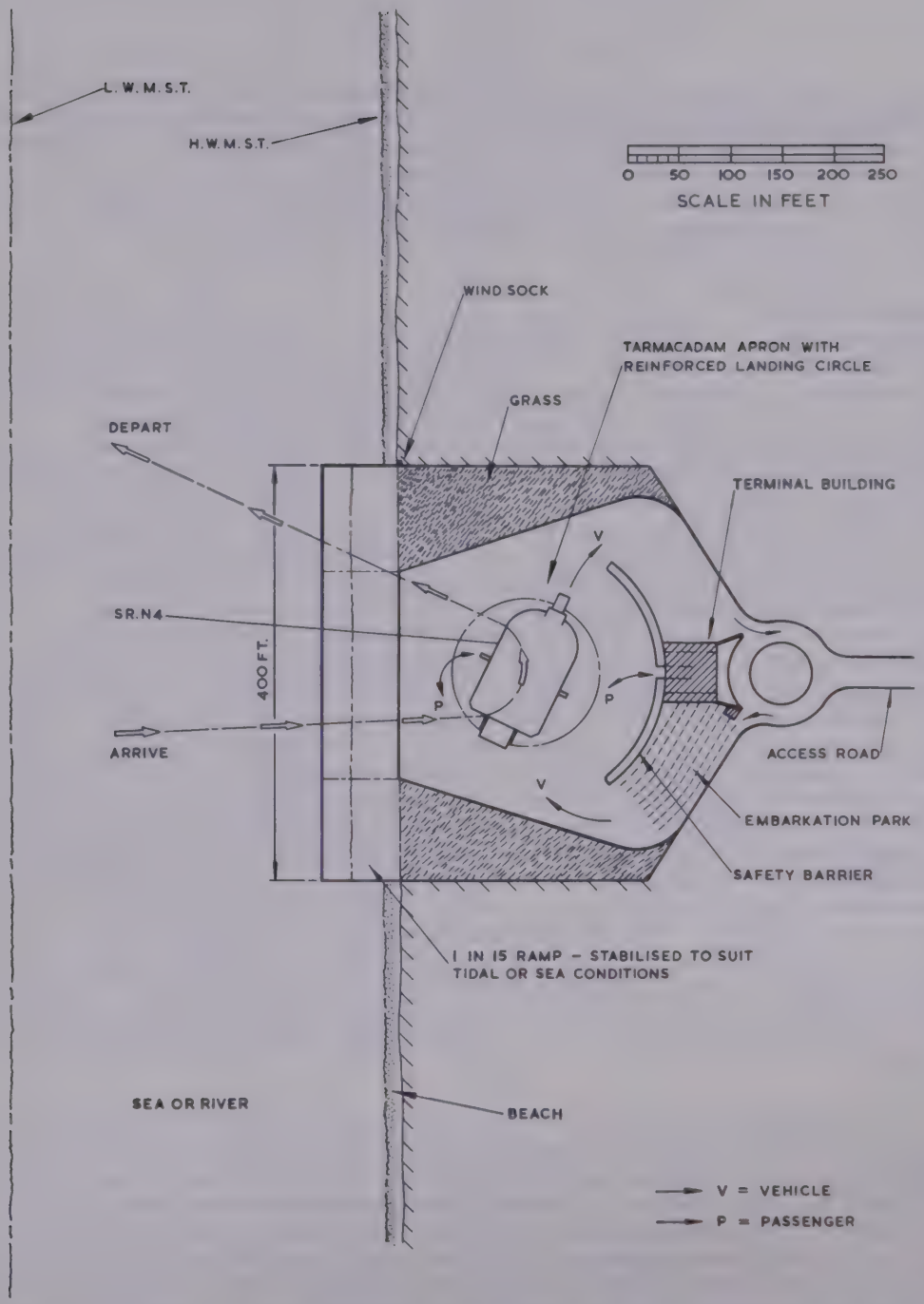

FIG. 5.1 MINIMUM HOVERHALT FOR DOMESTIC SERVICES

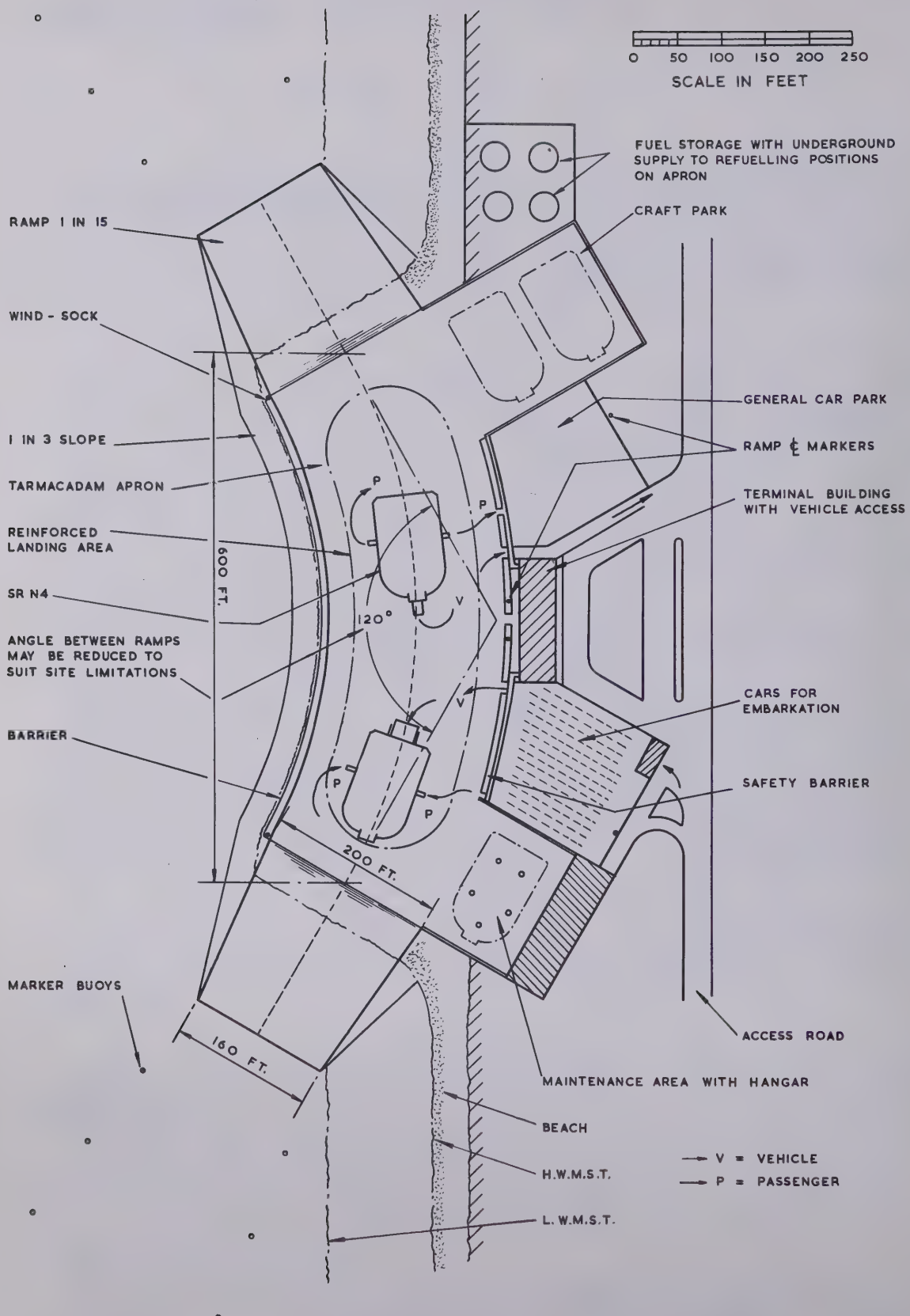

FIG. 5.3 HOVERPORT FOR HIGH – FREQUENCY DOMESTIC SERVICES

The landing area has been increased to allow two craft to be accommodated at any one time, which theoretically makes it capable of handling up to 15 arrivals and 15 departures an hour, i.e. 30 movements per hour. If all the craft were full this would lift approximately 4,500 passengers and 500 cars in each direction per hour. This can be compared to London Airport where the standard busy hour rate for aircraft movements is 64, i.e. just over twice the above. Thus, this size of hoverport, which occupies only 10 - 15 acres compared to 2,000 acres of London Airport, could be expected to handle, on a 'domestic' route, about the same number of passengers per hour plus the car traffic, its relative cost being approximately in the ratio of the areas.

Baggage and freight are handled manually on the layout shown. Should freight become a significant part of the traffic, mechanical freight-handling facilities would have to be installed, particularly with respect to the handling of containers and pallets. Covered walkways could be provided to take the passengers as close as possible to the loading position. Refuelling is assumed to be done from hydrants fed from the tank 'farm' on the left of the diagram.

Recessed ramp hoverport within harbour

Very often a 'corner' of a harbour is not used by shipping because of shallow water. If this is filled, as for example at Boulogne, then a ready made site for a hoverport exists. Ideally, as already described, it should have two approaches but providing the site is reasonably remote or mechanical means such as a turntable or land 'tugs' are used to turn the craft, then there is no reason why an acceptable single ramp base cannot be devised.

A possible arrangement is shown in fig.5.4. The main features are a recessed ramp leading to an apron having a central landing area beyond which are the passenger and car handling arrangements. A park for a second craft, or one being serviced, could be provided to one side if required; in any case, it would be possible to park two craft on the landing area overnight, although only one can be operated from an area of the size shown on an 'in service' basis. While the turn-round from such a base would not be quite as good as for a twin slipway type, the site availability and the relatively cheap cost (no exposed ramps and small area) might make it attractive under certain circumstances.

Operation from a harbour quay

Providing a very sheltered location can be found it is possible to operate the SR.N4 from a quayside as shown in fig.5.5. However, the low freeboard of the bow ramp means that rough water cannot be tolerated; furthermore, if the tidal range is more than approximately 2 ft., then an adjustable angle ramp must be provided to take care of tidal variations.

As shown in the diagram the SR.N4 is moored to an arm at right angles to the main quay, this avoids the shore ramp conflicting with that required for a conventional bow loading car ferry and places the special fenders required for the hovercraft where they will not be damaged by conventional shipping.

Clearly, the craft could, with assistance from the shore winches, be moored stern on to the main quay but this lengthier procedure should seldom be necessary if the other bases on the routes are of the recommended type which would allow the vehicular traffic loaded 'bow on' to drive off at the stern.

SAFETY BARRIERS

Where there is a steep drop from the apron or danger of a craft caught in a side gust injuring personnel on another part of the base, then safety barriers must be provided to check the motion of the craft. These must act through the skirt, typical proportions being shown in fig.5.6.

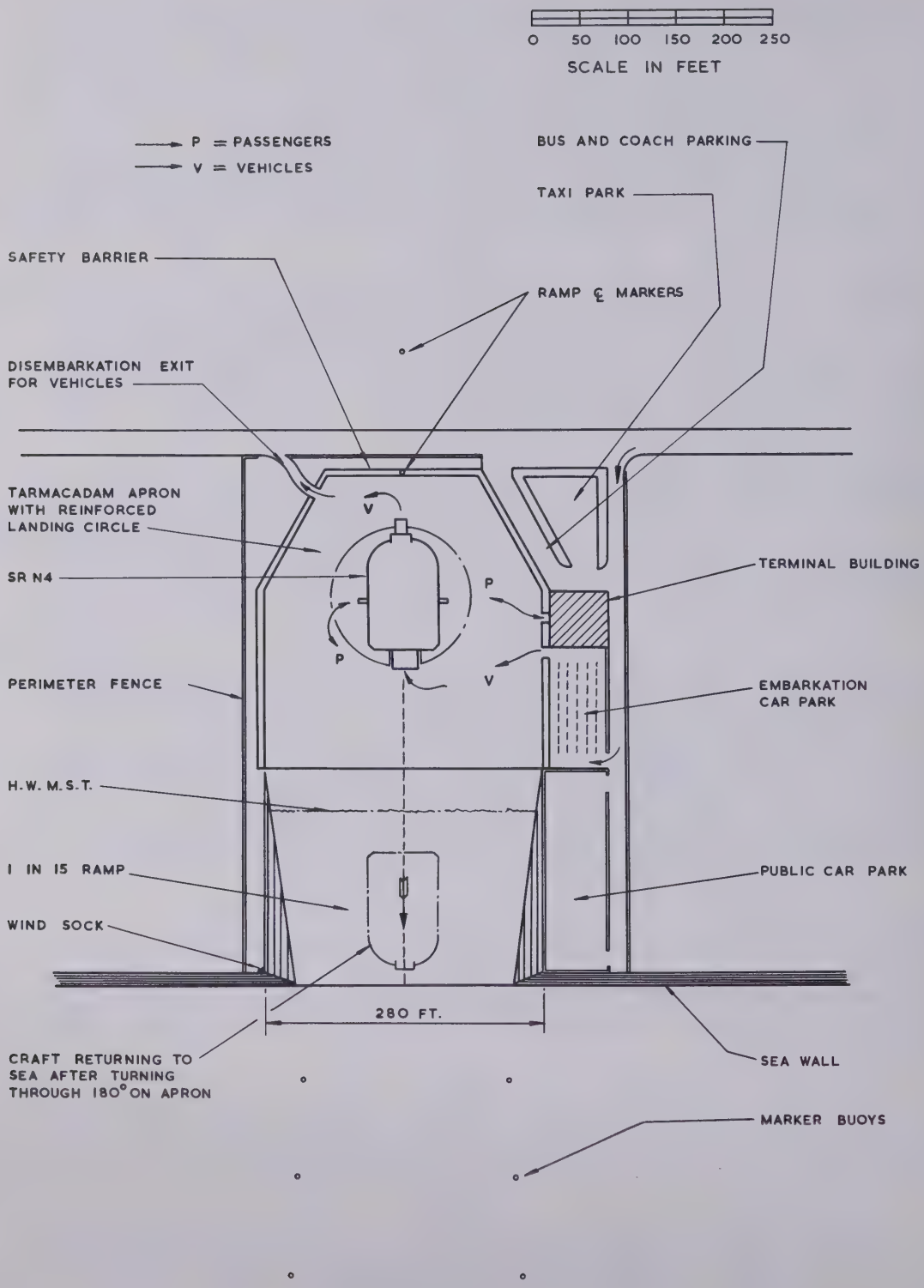

FIG. 5.4 RECESSED RAMP HOVERPORT WITHIN HARBOUR

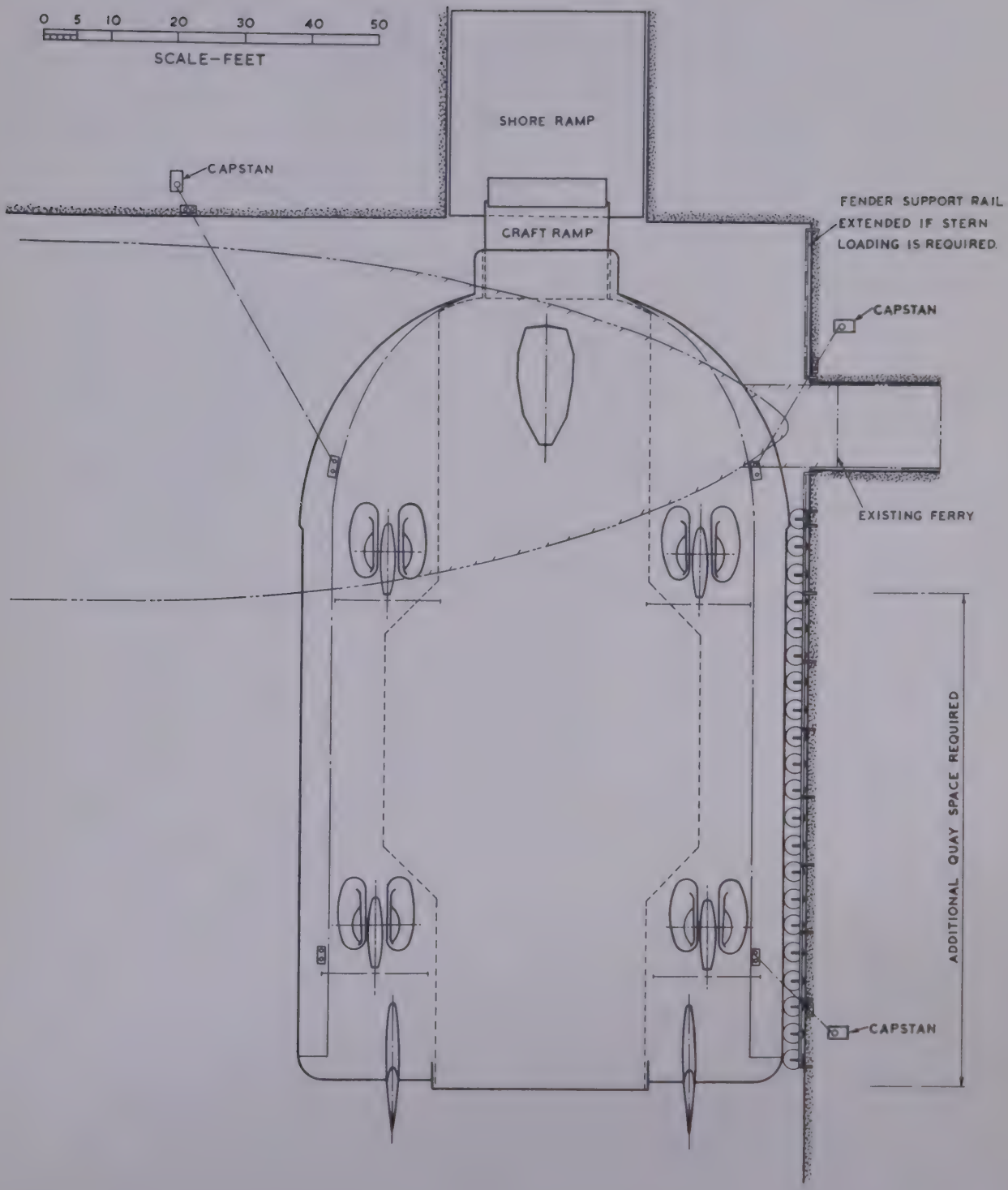

FIG. 5.5 BOW LOADING FROM QUAY

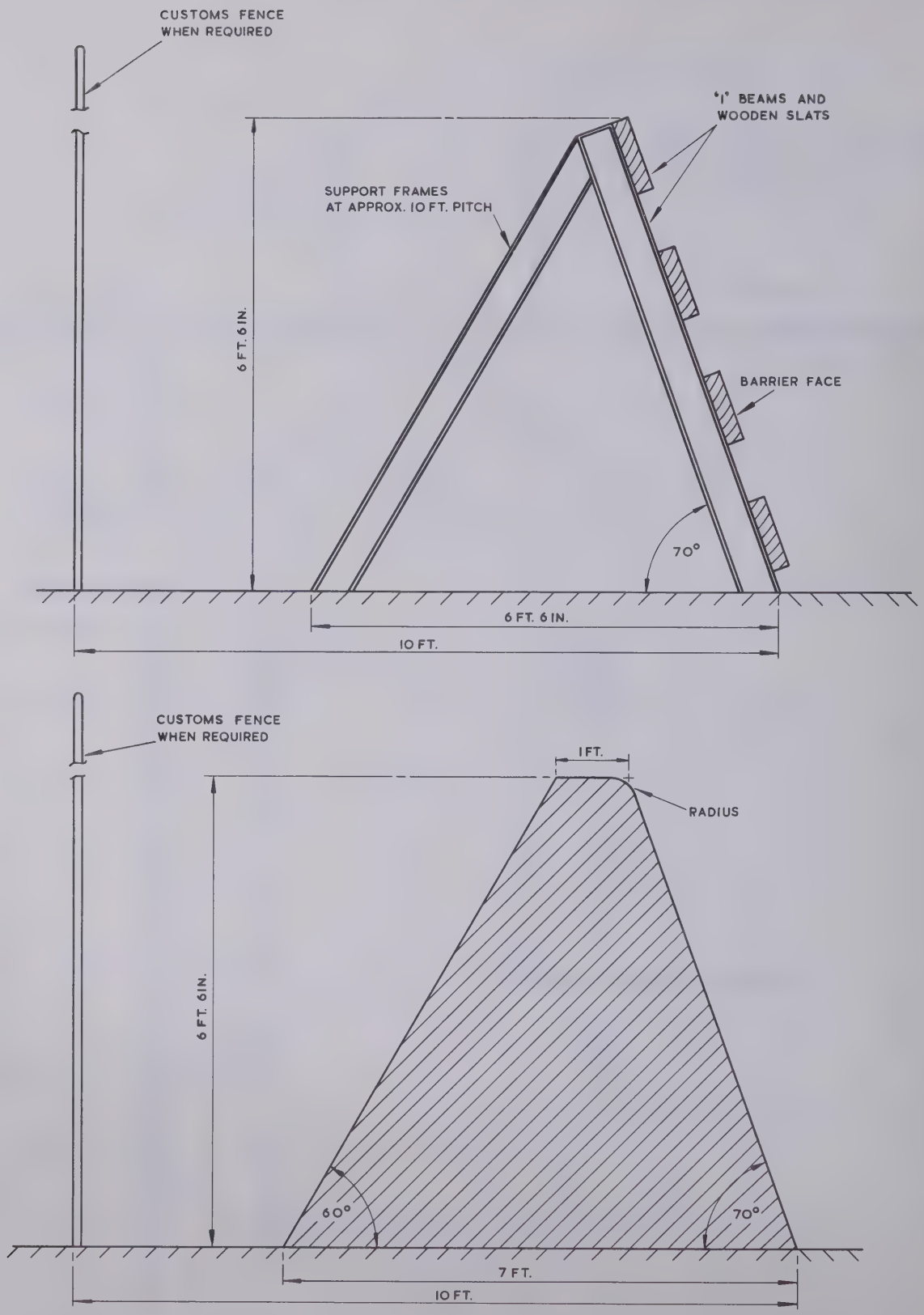

FIG. 5.6 SAFETY BARRIERS

alternative layouts

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alternative layouts

The basic design of the SR.N4 is such that without major modification to the craft the ratio of passengers to cars can be varied to suit the type of traffic to be handled and the length of the route over which the service is operated.

An all-passenger layout has been projected and provides for 605 seated passengers. The facilities provided, that is, bars, toilets etc., would depend upon the duration of the trip and the route over which the craft was operating.

The layouts shown by no means illustrate all the possibilities of the craft but are typical examples of the alternatives to which the craft can be modified.

alternative layouts

SHORT RANGE (up to 15 miles)
Passenger/car version
This layout is suggested for a very short range route, such as the Solent, where turn-round time is likely to be as long as, or longer than, journey time when operating at maximum capacity.

To this end it is suggested that car passengers should remain in their cars, the number of foot passengers being limited by the reduced number of seats relative to the basic craft layout.

Seats against the centre cabin inner wall have been deleted to allow maximum baggage space and a free walkway for passengers going through to the forward cabin.

Car space remains as for the basic craft but the passenger seats have been reduced to 134.

Estimates based on simulated loading trials and comparative timings from local conventional vehicle ferries indicate that under favourable conditions turn-round times as low as five minutes could be achieved. An important parameter here is that the drive on drive off facility is used.

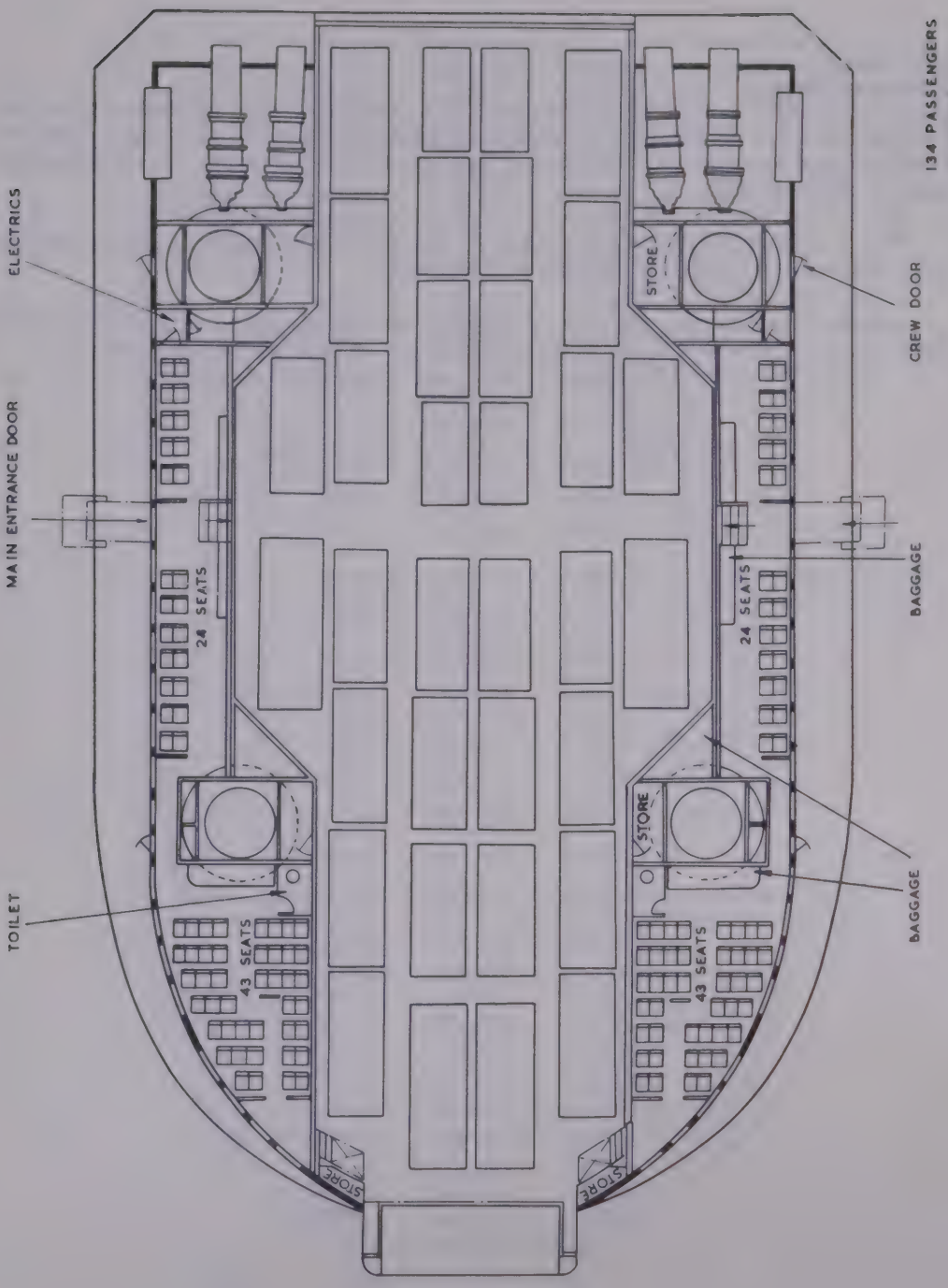


FIG. 6.1 SHORT – RANGE PASSENGER/CAR VERSION

alternative layouts

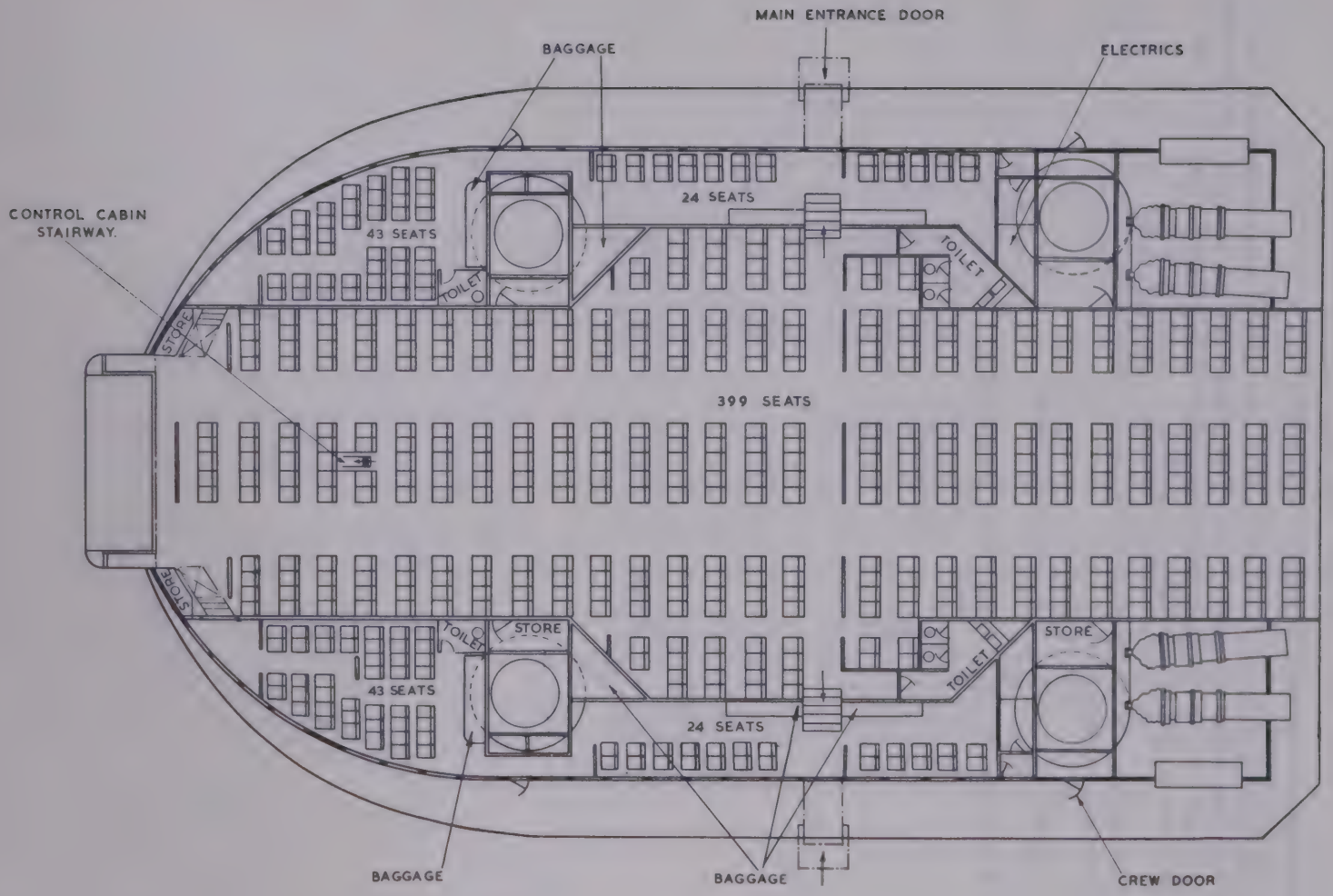
SHORT RANGE

All–passenger version

Again for short-range routes this layout is suggested for commuter type all-passenger traffic. The very wide gangways would assist rapid passenger flow during turn-round and allow approximately 140 standing passengers. Seated passenger capacity shown is 533.

With a seat pitch of approx. 47 in. passengers on a short sea route would be able to keep their baggage with them at all times.

Allowing for a certain amount of overlap and using bow ramp, stern and side doors, turn round times in this role should be of the order of 10 minutes.



533 SEATED PASSENGERS
140 STANDING PASSENGERS

FIG. 6.2 SHORT – RANGE PASSENGER VERSION

alternative layouts

MEDIUM RANGE (15 – 100 miles)
Passenger/car version

This version has been provided with seating additional to that in the basic craft but with four less cars. The bays on each side of the car deck have been converted into passengers saloons to accommodate an extra 80 passengers, thereby increasing the total seating capacity to 254.

Passengers will not remain in their cars but would obviously not require stowage room for their baggage.

Additional toilets are provided in this layout.

With this craft it is anticipated that the turn-round times would be about 15 min.

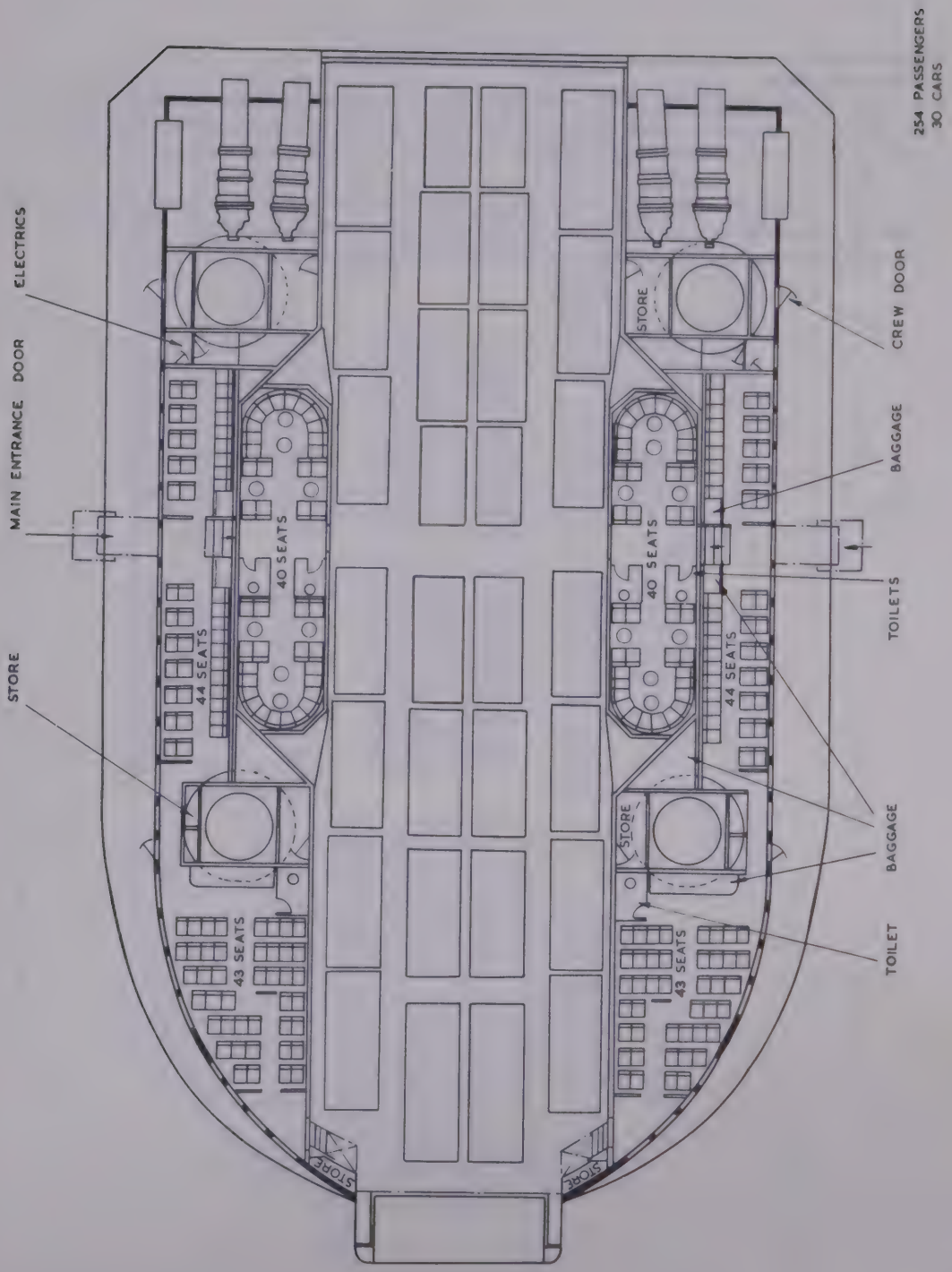


FIG. 6.3 MEDIUM – RANGE PASSENGER/CAR VERSION

alternative layouts

MEDIUM RANGE

All–passenger version

This layout accommodates 609 passengers and is an adaptation of the basic craft. The seats are at 31 in. pitch and it is assumed that passengers' baggage is stowed at the rear of craft in compartments on each side of the bar and refreshment stores.

Even on routes of $\frac{3}{4}$ to $1\frac{1}{2}$ hr. duration, it is unlikely that full meal service will be either required or possible for 605 people and hence facilities are limited to light refreshments and, for international routes, duty free sales.

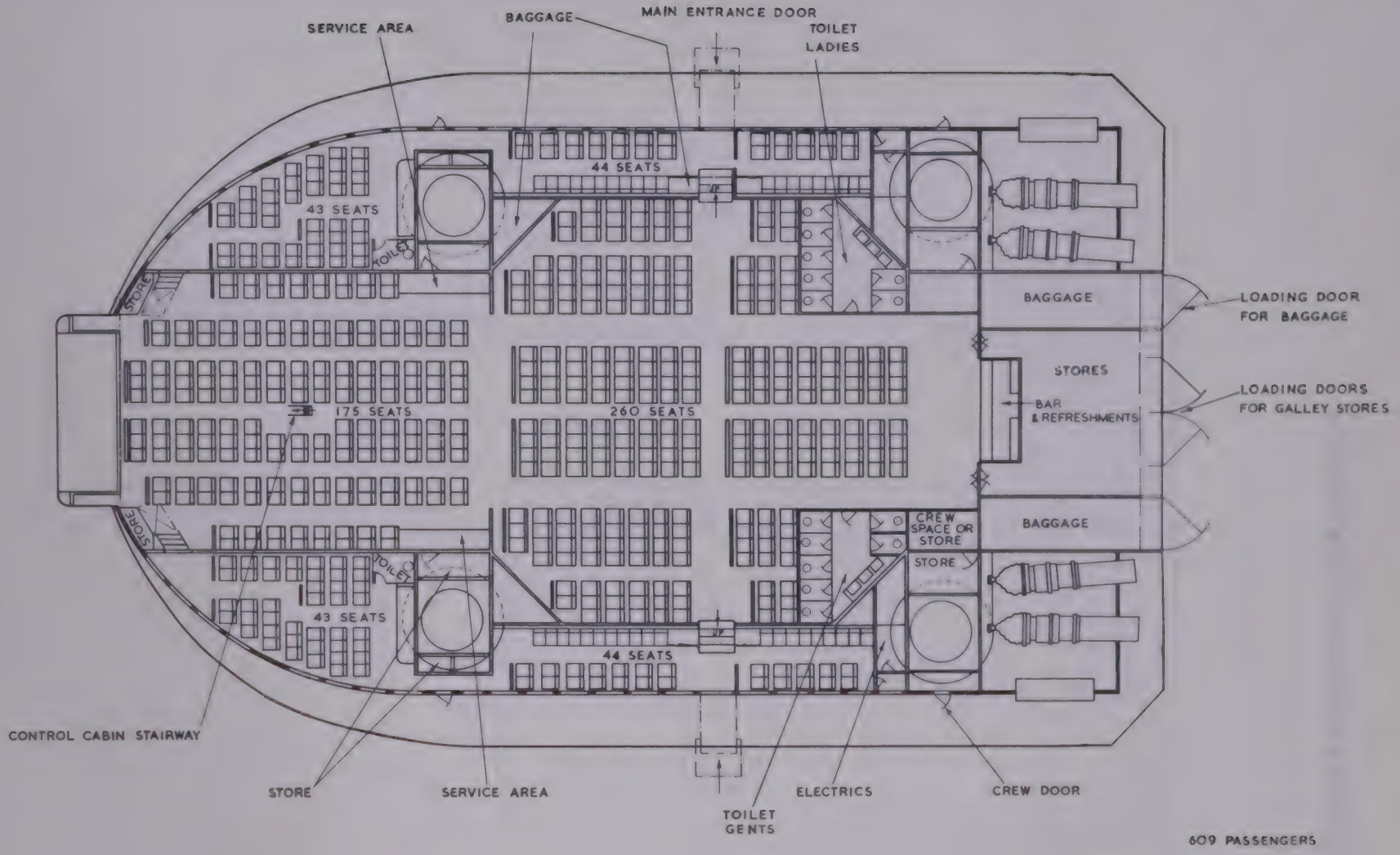


FIG. 6.4 MEDIUM – RANGE PASSENGER VERSION

alternative layouts

LONG RANGE (over 100 miles)
Passenger/car version

The passenger accommodation has been increased on this version at the expense of the car deck area to include 73 additional seats each side, a 32-seat dining saloon on the port side and a 43-seat refreshment saloon on the starboard side. With this arrangement, 16 cars and 363 passengers can be carried.

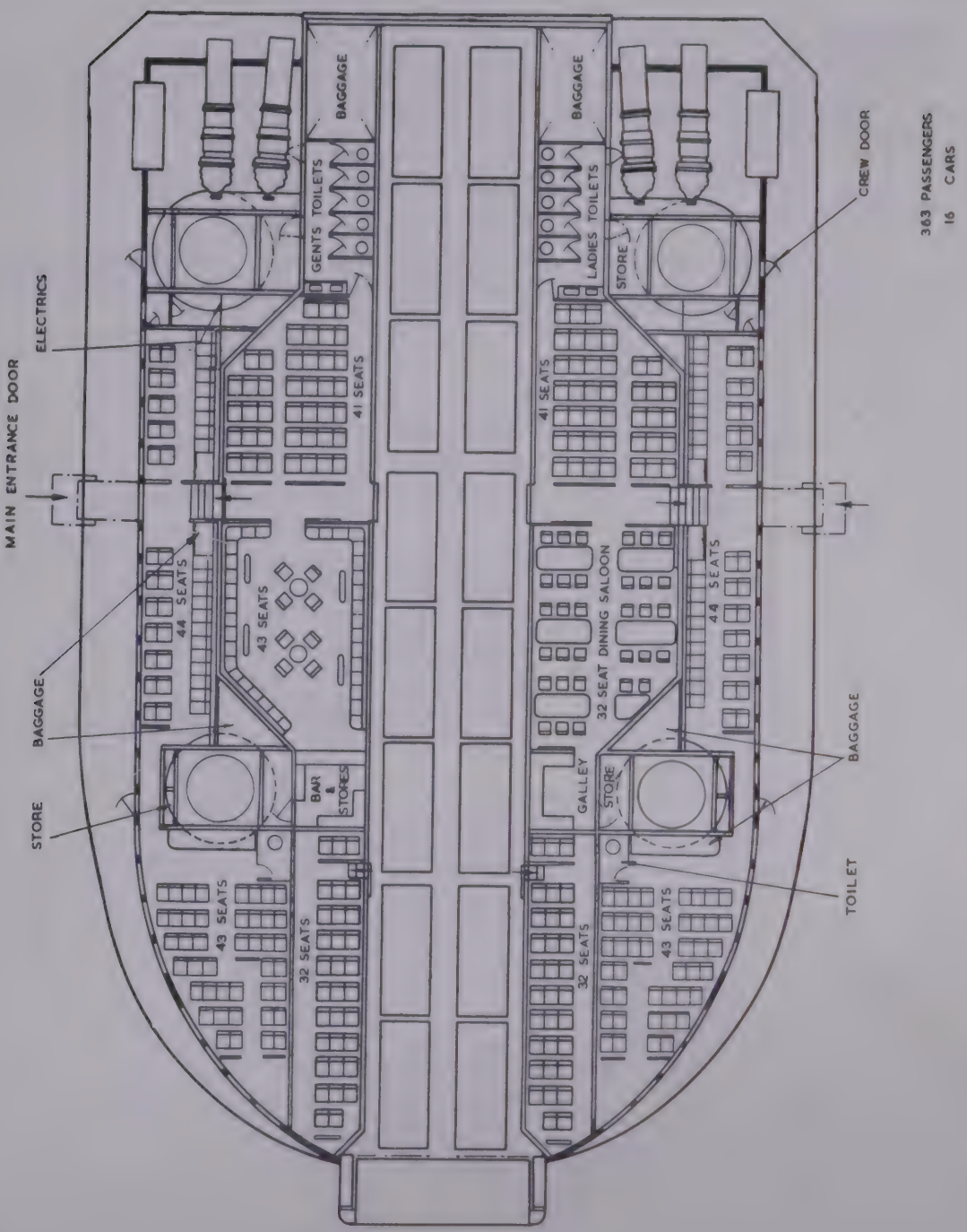


FIG. 6.5 LONG – RANGE PASSENGER/CAR VERSION

alternative layouts

LONG RANGE

All–passenger version

This layout is very similar to the medium-range version, some of the rear seats have been replaced by a dining area, more emphasis being placed on refreshment and meal service.

On the longer routes turn-round times are likely to be at least half an hour to include stores replenishing and refuelling.

If specially ordered it would be possible to fit this craft with a special 'vista bow' in place of the ramp extension to give increased visibility for the passengers in the centre deck.

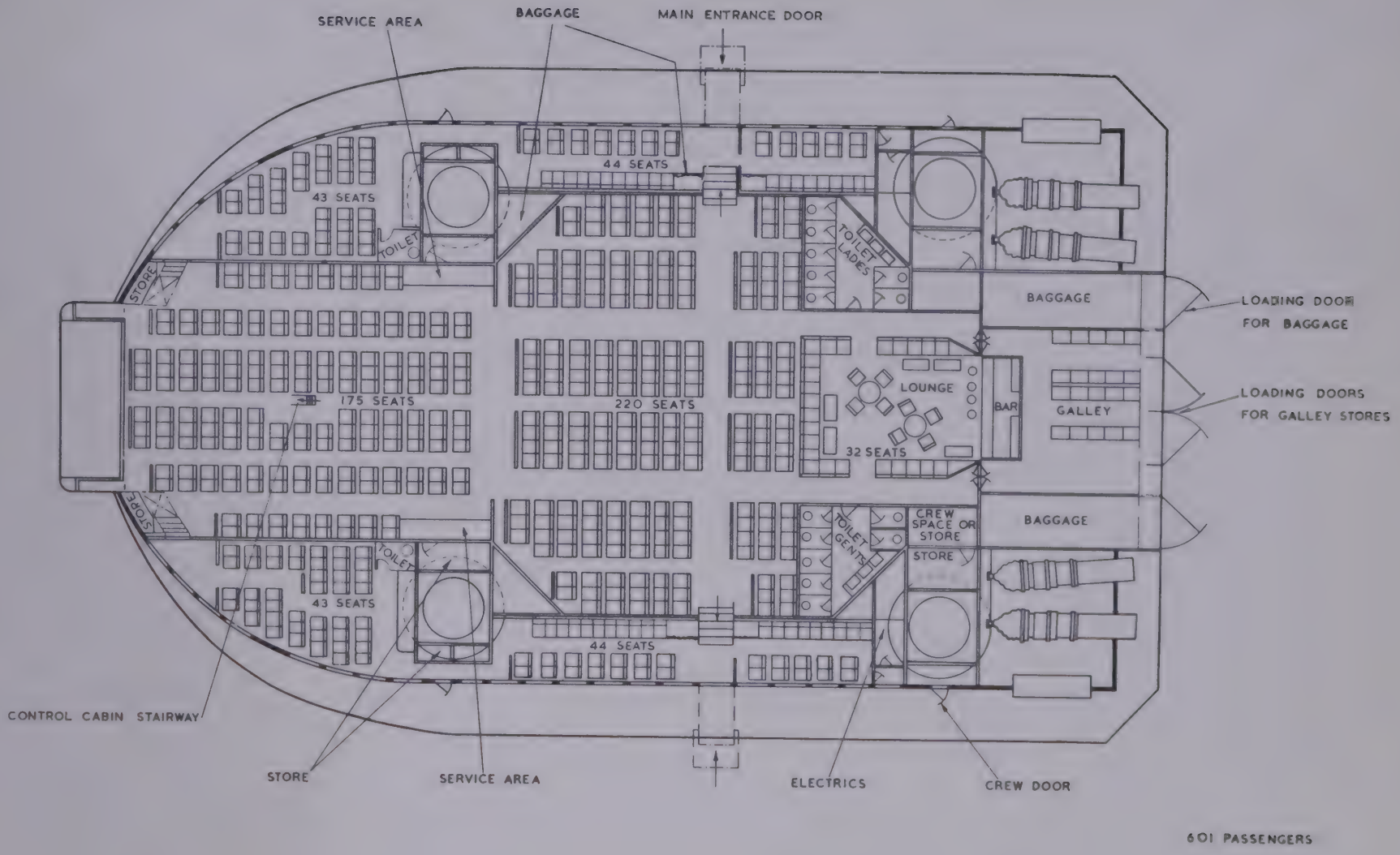


FIG. 6.6 LONG – RANGE PASSENGER VERSION

customer proposal

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